REUSE ECONOMICS SPREADSHEET MODEL USER MANUAL

SPC-91158-CMC

VERSION 03.00.08

JULY 1993

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Produced by the
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PREFACE

The Reuse Economics Spreadsheet Model tool implements various portions of the software reuse economics model described in Cruickshank and Gaffney (1991). The model described in the report was conceived to demonstrate the economic benefits of software reuse. You should be thoroughly familiar with this report to most effectively use the tool.

The Reuse Economics Spreadsheet Model tool was designed to help you evaluate the potential impact of various reuse strategies on the costs of software products. The tool provides both spreadsheet and graphics capabilities. It requires the use of Microsoft Excel, version 4.0, and can operate on either a Macintosh or an IBM-compatible PC.

The tool can operate in any one of five modes:

- Mode 1a: Basic Model—Reuse With Up-Front Reuse Program Investment
- Mode 1b: Intraproject Reuse
- Mode 2: Incremental Reuse Program Investment Without Cost of Money
- Mode 3: Incremental Reuse Program Investment With Cost of Money
- Mode 4: Basic Model Plus Reuse of Requirements and/or Design

  NOTE: Mode 4 provides a breakout of requirements and design.

The version of the tool documented in this user manual operates **only in Modes 1a, 2, and 3**.

The estimates of reuse costs, productivity, return on investment, and number of break-even systems implemented in the Reuse Economics Spreadsheet Model tool are just that—estimates. Mathematics cannot make estimates into certainties. It is very important for you, as the user of this tool, to note that the results of its application can be no better than the data it employs. If you do not have an accurate idea of how much it costs to create new code, to reuse code, and to invest in a reuse program, the numbers that the tool generates will be correspondingly inaccurate.

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ACKNOWLEDGEMENTS

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1. INTRODUCTION

1.1 OVERVIEW

This document is the user manual for version 3 of the Reuse Economics Spreadsheet Model tool, which provides automated support for performing economic analyses of various software reuse strategies. The tool is implemented on version 4.0 of the Microsoft Excel spreadsheet. You can operate it using either a Macintosh or an IBM-compatible PC. It provides both spreadsheet and graphics capabilities.

NOTE: Due to the incompatibility between versions of the tool, any existing data from previous versions will need to be reentered for use in version 3.

Section 2 summarizes the model, which is presented in detail in Cruickshank and Gaffney (1991). You should become familiar with this report before using the Reuse Economics Spreadsheet Model tool to use it with maximum effectiveness.

1.2 BACKGROUND

A software system consists of two categories of code: **new** and **reused** (Gaffney and Cruickshank 1992; IEEE 1993). New source statements are those newly created or modified for the software system. Reused source statements are those unmodified source statements obtained for the product from an external source, which could be a reuse library (IEEE 1993). The object of reuse is to avoid building a new software product entirely from scratch. The major benefits that can be realized from reuse include:

- Reducing development and overall life cycle costs, thus saving money and enhancing productivity
- Enhancing software product quality
- Reducing the amount of time required for development
- Enabling more software to be developed, thus reducing software applications backlog

Investment is required for an organization to realize the benefits of a reuse program. Such investment may be in such items as: program planning and the initial stages of implementation, the characterization of application systems that will benefit from reuse, the location and collection of reusable software, the definition of domains, the establishment of reuse libraries or repositories, and the development of systems to aid in the instantiation of reused software into application systems. All are important components of the investment in a reuse program. A given reuse program may not include all of these components, but it will include some of them. Thus, an investment will be required. It is necessary to plan both the amount of investment and the pattern of investment. The spreadsheet

tool presented here offers help in performing "what if" analyses to aid in this planning. The Reuse Economics Spreadsheet Model tool supports investigations of the economic viability of software reuse in specific situations.

1.3 AUDIENCE AND PURPOSE

The intended audience for the Reuse Economics Spreadsheet Model tool includes senior-level line engineers, project managers, and operational area managers interested in exploring economic trade-offs involved in software reuse. You can use the Reuse Economics Spreadsheet Model tool to help you analyze the potential impact of adopting various reuse strategies on the overall cost of software development. The tool enables you to examine the effects on the software product development cost of varying certain parameters, such as the proportion of code reused, the unit cost of development for new code, and the unit cost of reusing code.

1.4 USER MANUAL ORGANIZATION

This manual describes how to use the Reuse Economics Spreadsheet Model tool. It illustrates some of the ways you can analyze the potential impact of adopting various reuse strategies on the overall cost of software development. The main body of the manual is organized as follows:

- Section 2, Modes of Operation, summarizes the reuse economics models implemented in the tool.
- Section 3, Invoking the Tool, describes how to install and open the Reuse Economics Spreadsheet Model tool.
- Section 4, Operating the Tool, describes the menu bar selections and windows presented when using the tool.

Appendix A, Reuse Economics Mathematical Models, presents guidelines to follow to derive estimates of the parameters that drive the model.

The Glossary section provides definitions for terms used in this manual.

The References section identifies sources of information used in this manual.

1.5 TYPOGRAPHIC CONVENTIONS

This manual uses the following typographic conventions:

Serif font	General presentation of information.
Italicized serif font	Publication titles.
Boldfaced serif font	Section headings and emphasis.
[ ]	Screen buttons.
< >	Workstation keyboard key names, such as <RETURN> for the Return key.

2. USING THE TOOL

2.1 SECTION OVERVIEW

This section describes how you can use the Reuse Economics Spreadsheet Model tool to aid you in analyzing the costs and related economic parameters of interest in connection with the development of new application software systems that are composed, in part, of reused code. You should find the tool to be useful in various situations, such as product planning and forecasting, developing cost proposals, and analyzing the potential payoff of investment in reuse support and other software development technology. The tool has three modes of operation, each of which provides an analysis support capability. This section summarizes those capabilities. The tool can help you to answer various questions concerning the cost and related parameters of new systems constructed, in part, of reused code. This section cites some of these questions. It also provides you guidance for selecting the values of the three principal cost parameters used in the operation of the tool. Other sections of this manual provide additional details about using the tool and the nature of the mathematical models that it implements. Section 4 shows you how to operate the tool, stepping you through the operation of each of its modes of operation. Appendix A presents the mathematical models that underlie the operation of the tool.

2.2 REUSE ECONOMICS BACKGROUND

This section provides some background about the costs of developing new application software systems that consist of new and reused code that should aid you in exploiting the capabilities of the Reuse Economics Spreadsheet Model tool.

The cost of developing a new application system is equal to the sum of the prorated cost of **domain engineering** plus the cost for creating the particular application system, the **application engineering** activity. Domain engineering is the capital investment involved in the process of making **reusable software objects** (RSOs) to be employed in a **family** of application systems. A family is a set of application systems that are similar (Parnas 1976). Each of the application systems in a family includes reused software components from a repository or library. The similarity among application systems in a family is evidenced by the amounts of their reuse of library components. The model tool defines the **capacity** of the library as the proportion of the application system code that is provided by the library or repository of RSOs. The model also defines a related parameter, the library **efficiency**; this is the proportion of RSOs in the library actually used in an application system.

One tool user's view of the economics of reuse may differ from that of another. In some cases, the cost of reuse program investment may not be a consideration to a user. For example, if a contractor for the government receives the RSOs free from the government for incorporation into an application system (or an entire family of application systems), he probably would not use the reuse program

investment or domain engineering term in the cost model when evaluating his cost picture. However, the government program manager, program executive officer, or other such official would probably be very interested in issues such as the likely payoff on his investment and, thus, would use the domain engineering term in the model. Similarly, a government contractor or other developer of software would use the investment (domain engineering term) to facilitate his consideration of the economics of investing in the creation of a family of systems.

The models implemented in the tool assume that there is code reuse as well as reuse of the corresponding design and requirements. Other reuse regimes are possible, such as where there is some or even no code reuse but there is reuse of design and requirements. Section G.2 of the *Reuse Adoption Guidebook* (Software Productivity Consortium 1992a) and the paper by Gaffney and Cruickshank (1992) describe such more general cases of reuse. The models implemented in this version of the tool do not represent such situations; however, they may be covered by another mode of operation implemented in a future version of the tool.

2.3 SELECTING THE RIGHT MODEL

The Reuse Economics Spreadsheet Model tool provides three different modes of operation to help you determine the answers to various cost related questions, such as those indicated above. The three modes are:

- Mode 1a—Basic Model
- Mode 2—Incremental Reuse Program Investment *Without Cost of Money*
- Mode 3—Incremental Reuse Program Investment With Cost of Money

The applicability of each mode is summarized in Table 2-1.

Table 2-1. Mode/Model Capability Summary

Mode/Model	Capability
Mode 1a—Basic Model	You should use this mode to represent cases in which all of the reuse program investment (domain engineering) is done at one time up front, simultaneously with, or before the development of the first application system of the family of systems. Also, you can use this mode without the investment term to represent the case of no investment: • When you reuse software whose cost was expensed by the project that developed it • If your organization is not doing the investment (e.g., if you receive the software free from the government) • When the cost of doing it is provided under a separate contract

Table 2-1, continued

Mode 2—Incremental Reuse Program Investment Without Cost of Money	This mode provides a generalization of the model used in Mode 1a. You should use this mode to represent the case in which all of the reuse program investment (domain engineering) is not done up front but is done incrementally. You should use this mode if you want to use a more general model than that provided in Mode 1a that allows different costs to be used for developing new software or reusing software or different amounts of reuse in each of the application systems in the family of systems under consideration. This mode also enables you to represent the situation in which the costs of developing or reusing code change over the period of development of a family of systems. Thus, you can use it to reflect the impact of software development technology improvement in your development organization over this period.
Mode 3—Incremental Reuse Program Investment With Cost of Money	You should use this mode in any of the circumstances in which you would apply the Mode 2 model **and** in which you wish to represent the effect of the cost of money.

You should note that the model implemented in Mode 1a of the Reuse Economics Spreadsheet Model tool assumes that the cost of domain engineering (or reuse program investment) is incurred "up front" at or before the creation of the first of the set (or family) of application systems. Modes 2 and 3 provide more general models in which the reuse program investment costs may be incurred at several times during the period that the set or family of application systems is developed. Mode 2 supports the examination of the case of incremental reuse program investment without considering the cost of money, and Mode 3 supports the examination of the case of incremental reuse program investment considering the cost of money.

2.4 REUSE COST QUESTIONS AND THE TOOL

You can use the Reuse Economics Spreadsheet Model tool to help you answer various questions about an analysis of the economics of reuse in your development environment. Section 2.4 presents some of the questions that you might pose during an analysis of the economics of reuse and relates them to the portions of Section 4 that are relevant. Section 4 illustrates the operation of the tool, including the generation of various graphs, with simulated project data. The tool provides you with graphical outputs as stated. It also provides you with more data on the spreadsheet, as illustrated in Section 4, for each example covered. Note that Section 2.5 provides detailed guidance on the selection of the three principal cost parameters cited with reference to the cost questions below: the Unit Cost of Reuse Program Investment, the Unit Cost of New Code, and the Unit Cost of Reused Code.

- What is the increase in the productivity of developing a new system for a given amount of code reuse?

You can use the Relative Product Productivity vs Proportion of Code Reuse Graph provided by Mode 1a (see Section 4.4.6) to help you answer this question. This graph provides you with plots of **Relative Product Productivity** (productivity of creating the application system with reused code relative to productivity if only new code were used in the development effort) versus **Proportion of Code Reuse**. You can obtain up to three different plots on the graph that differ with respect to the **Number of Application Systems**. You enter Number of Application Systems, Proportion of Code Reuse, Library Efficiency, the Unit Cost of Reuse Program Investment, the Unit Cost of New Code, and the Unit Cost of Reused Code. The tool calculates Relative Product Productivity and Relative Library Capacity. The tool also calculates the **Product Productivity** based on your inputs using an equation described in Appendix A and then obtains the **Relative Product Productivity** from it by relating it to the Unit Cost of New Code.

- How is the productivity of developing a new system affected by the cost of reusing code?

  You can use the Relative Product Productivity vs Relative Reuse Cost Graph provided by Mode 1a (see Section 4.4.6) to help you answer this question. This graph provides you with plots of **Relative Product Productivity** (productivity of creating the application system with reused code relative to productivity if only new code were used in the development effort) versus **Relative Reuse Cost**. You enter the same data as described in connection with answering the preceding question. The tool calculates the **Relative Reuse Cost** (the unit cost of reusing code relative to the unit cost of developing new code) based on the data that you have entered. The tool also calculates the **Product Productivity** based on your inputs using an equation described in Appendix A and then obtains the **Relative Product Productivity** from it by relating it to the Unit Cost of New Code. You can obtain up to three different plots on the graph that differ with respect to the **Proportion of Code Reuse**.

- How is the productivity of developing a new system affected by the number of systems that share ("reuse") code?

  You can use the Product Productivity vs Number of Applications Graph provided by Mode 1a (see Section 4.4.6) to help you answer this question. This graph provides you with plots of **Product Productivity** (productivity of creating the application system, including the effect of employing reused code in it) versus **Number of Application Systems**. You enter the same data as described in connection with answering the preceding question. The tool calculates the **Product Productivity** based on your inputs using an equation described in Appendix A. You can obtain up to three different plots on the graph that differ with respect to the **Proportion of Code Reuse**.

- How many application systems must I plan to develop for a certain investment in reuse to pay off (break even), based on prorating the cost of that investment over those systems?

  You can use the Return on Investment vs Number of Applications Graph provided by Mode 1a (see Section 4.4.6) to help you answer this question. This graph provides you with plots of **Return on Investment** versus **Number of Application Systems**. You can obtain up to three different plots on the graph that differ with respect to the **Library Efficiency**. You enter Number of Application Systems, Library Efficiency, the Unit Cost of Reuse Program Investment, the Unit Cost of New Code, and the Unit Cost of Reused Code. The tool calculates the Return

on Investment based on the data that you enter. It also calculates the Number of Break-Even Systems for each of up to three graphs you have plotted. This is the number of application systems in a family of systems at which the total cost of developing the application systems with all new code is equal to the total cost of developing them with the proportion of reused code that you have stipulated. The number of application systems in the family must exceed the break-even figure for the investment in reuse to pay off.

- What is the cost of developing each of a set ("family") of similar systems given that I plan a certain domain engineering (capital investment) strategy for the development of RSOs whose development cost is to be amortized over a set ("family") of similar systems that will use them?

  You can use the Labor Months vs Number of Application Systems Graph provided by Mode 2 (see Section 4.5.7) to help you answer this question. This graph provides you with four bar graphs for each application system in the family of systems whose costs you are considering. They are Reuse Program Investment (associated with the development of this application system), Cost per System With All New Code, Application Engineering Cost (development cost) per System, and Reuse Program Investment Cost per System. The last item is the pro rata allocation of the reuse program cost allocated to the development of this particular application system. The tool calculates all of the bar graph values. You consider a family of systems. For each family, you enter the Family Number and Number of Application Systems in that family, and the total Size of the Reuse Library. Then, for each family member, call it the i^{th}, you enter the Application Number, the Unit Cost of New Code for the i^{th} Application System, the Unit Cost of Reused Code for the i^{th} Application System, the Amount of Reuse Library associated with the i^{th} Application System (how much of the total library of RSOs will be developed in association with the creation of the i^{th} application system), the Amount of New Code Developed for the i^{th} Application System, and the Amount of Reused Code Incorporated in the i^{th} Application System. The tool calculates the Total Size of the i^{th} Application System, the Relative Library Capacity for the i^{th} Application System, and the Unit Cost for the i^{th} Application System. Mode 2 and these plots do not consider the effect of the cost of money. The cost of money is covered by Mode 3 operation (see next question).

- What is the cost of developing each of a set ("family") of similar systems given that I plan a certain domain engineering (capital investment) strategy for the development of RSOs whose development cost is to be amortized over a set ("family") of similar systems that will use them for some cost of money?

  You can use the Labor Months vs Number of Application Systems Graph provided by Mode 3 (see Section 4.6) to help you answer this question. This graph provides you with four bar graphs for each application system in the family of systems whose costs you are considering. They are Reuse Program Investment (associated with the development of this application system), Cost of Money per System, Application Engineering Cost (development cost) per System, and Reuse Program Investment Cost per System. The tool calculates these values for you. In addition to the data that you have to enter to answer the preceding question, when answering this one (and operating the tool in Mode 3), you must also enter the Interest Rate (the cost of money) and the Number of Years (between the developments of the application systems in the family).

2.5 GUIDELINES FOR ESTIMATING PRINCIPAL MODEL PARAMETERS

A key aspect of using the cost models implemented in the Reuse Economics Spreadsheet Model tool is selecting appropriate values of the parameters used in it. This section provides you guidance for selecting values for the three principal cost parameters used in the tool.

The Reuse Economics Spreadsheet Model tool defines the cost (LM or labor months) of creating a new software application system as the sum of:

- The cost of domain engineering prorated over the number of application systems that use the code that the domain engineering activity produces
- The cost of developing the new code made especially for this application system
- The cost of reusing existing code in the application system obtained from the repository or other source

Each of these costs is given as the product of a unit cost (LM per thousand source lines of code [KSLOC]) and the amount of code (KSLOC) to which it applies. The remainder of Section 2.5 tells you how to select values of the unit costs of domain engineering (C_{DE}), developing new code (C_{VN}), and reusing code (C_{VR}). You must have or be able to estimate values of the parameters C_{VN}, C_{VR}, and C_{DE} to be able to successfully apply the tool to any reuse economics application.

The values of all of the parameters used in the tool are listed in Section 4. The dialog boxes in Section 4 associated with each mode define which parameters are entered and which are computed by the tool. Appendix A provides more detailed information about these parameters, defining them in terms of the mathematical models in which they are incorporated and which are implemented in the tool.

2.5.1 Selecting a Value of C_{VN}

You should select a value for C_{VN}, the unit cost of developing new code, based on your knowledge of the development process to be used in creating the application system or systems of interest. Alternatively, you can estimate the value of this parameter based on data from previous development projects. If actual values from several previous projects are available and if the set of development activities is the same or comparable to the new development effort contemplated, then the unit costs for all the projects (assuming the same type of software application) can be averaged. The *Software Measurement Guidebook* (Software Productivity Consortium 1992b) provides a comprehensive description of estimating software development costs that you should find useful in estimating C_{VN}.

Cruickshank and Lesser (1982) and Cruickshank (1987) show the software development unit costs for several development processes. These unit costs are values representative of actual development process performance based on accounting records that used a separate cost account for each activity within the development process. The later paper included the unit costs which are shown in Table 2-2. These unit costs are based on actual experience in the development of real-time command and control application software using the CMS-2 language.

The *Software Measurement Guidebook* (Software Productivity Consortium 1992b) shows the unit costs of an Ada-based development process. The 10.00 LM/KSLOC overall unit cost corresponds to some industry experience. This data is shown in Table 2-3.

The default value of C_{VN} in the Reuse Economics Spreadsheet Model is 5.00 LM/KSLOC. This is the value used in the examples in Section 4. You can override this value with your own value or you can use the data in Tables 2-2 or 2-3 as a basis for estimating a value of C_{VN} that is representative of your own development process.

Table 2-2. Software Development Process Unit Costs by Activity

Development Activity	Unit Cost (LM/KSLOC)
Requirements Analysis	0.300
Development Plan	0.150
Preliminary Design	0.600
Detailed Design	0.860
Test Plans	0.250
Software Tools (Utilities) Development	0.250
Design Evaluation (Reviews)	0.260
Code and CSU Test	2.400
Problem Analysis and Error Correction	0.640
Software Integration	1.500
Test Procedures	1.000
Acceptance Test	0.250
Total	8.460

Table 2-3. Ada Development Model Unit Costs

Activity	Unit Cost LM/KSLOC
Requirements Analysis	0.74
Preliminary Design	1.67
Detailed Design	2.22
Code and Unit Test	2.22
CSC Integration Test	1.60
CSCI Test	1.55
Total	10.00

2.5.2 Selecting a Value of C_{VR}

You can estimate the unit cost of reusing code in an application system, C_{VR}, by considering it in terms of its proportion of the cost of developing new code, C_{VN}. Values in the range of 0.20 to 0.30 for C_{VR}/C_{VN} are reasonable in the light of experience. A value of 0.31 is given in Margono and Rhoads (1992) for the cost of reusing software relative to the cost of developing new software. This value applies to the case of "domain specific reuse packaging." This same type of reuse experience is discussed in Cruickshank (1984 and 1987) for software in the CMS-2 language developed at IBM in Manassas, Virginia. Cruickshank (1984) gives the values of the cost of reusing software relative to developing new

software of 0.25 for modified reused code and 0.03 for unmodified reused code. Cruickshank (1987) also gives revised values of 0.31 and 0.04 for the same reuse types.

The principal element of cost in reusing code is that of testing the reused code in the presence of the new code. The cost of reusing code may also include the costs of revising existing test plans and procedures. Further, the cost of reusing code can include the cost of determining what code units are appropriate to reuse from the reuse library or other source. Using the data in Table 2-2 and assuming that the cost of reusing code is the cost of the activities of software integration test and acceptance test, you can calculate the cost ratio of reusing code to developing new code as (1.500+0.250)/8.460 = 0.21. Similarly, using the data in Table 2-3 and assuming that the cost of reusing code is the cost of computer software component (CSC) integration test and computer software configuration item (CSCI) test, you can determine the cost ratio of reusing code to developing new code as (1.60+1.55)/10.00 = 0.315. These ratios are in the same range.

The default value of C_{VR} in the tool is 0.5 LM/KSLOC, which is one-tenth of the default value of the unit cost of new code, i.e., $C_{VR} = 0.10 \cdot C_{VN} = (0.1)(5.00) = 0.5$ LM/KSLOC. This is the value used in Section 4. Without any other information, you can use a value of 2.0 (0.2 • 10.00) LM/KSLOC for C_{VR}.

2.5.3 Selecting a Value of C_{DE}

You can estimate the unit cost of domain engineering, C_{DE}, as a proportion of the unit cost of developing new code, C_{VN}. This proportion can be expected to be in the range of 1.50 to 2.00, and the value of 1.50 can be used if there is no other experience data available to the user of the tool. Margono and Rhoads (1992) suggest a value of 2.00 for the ratio of C_{DE} to C_{VN}.

You should estimate the value of C_{DE} based on your assessment of the nature of the process that will be employed to develop reusable components. If this process does not differ appreciably from that employed to develop new code that is not specifically reusable, then the value of C_{DE} would not be much greater than C_{VN}. However, if extra effort is required to make the code reusable, the C_{DE} value should be noticeably greater than that for C_{VN}, perhaps up to $2.0 \cdot C_{VN}$. Note that the size of the library is symbolized by S_T (see Sections A.2.2 and A.2.3 for more information about how to define the size of the library). Therefore, $C_{DE} \cdot S_T$ is the cost of developing the reuse program, which includes various items, such as developing reuse program goals, identifying strategies, forecasting the number of systems that will include RSOs from the library, and creating the RSOs. The *Reuse Adoption Guidebook* (Software Productivity Consortium 1992a) provides more information about the establishment of a reuse program.

The default value of C_{DE} used in the Reuse Economics Spreadsheet Model is 7.5 LM/KSLOC, which is 1.5 times the default value of C_{VN}, i.e., $C_{DE} = 1.5 \cdot C_{VN} = (1.5)(5.00) = 7.5$ LM/KSLOC. This is the value used in Section 4. Without any other information, you can use a value of 15.0 (1.5 • 10.00) LM/KSLOC for C_{DE}.

3. INVOKING THE TOOL

The Consortium has provided the Reuse Economics Spreadsheet Model tool as a set of Microsoft Excel files and executable files on a diskette. The tool will operate on either a Macintosh or an IBM-compatible PC. The files named ModeXDB.xls are likely to change in size over time. They grow or shrink in proportion to the number of worksheet rows. A prerequisite for the operation of the tool is to have version 4.0 of Microsoft Excel installed on your computer.

Microsoft Excel retains a list of recently opened files that displays in the File Menu. **Do not try to open the Reuse Economics Spreadsheet Model tool from this list.** Attempting to open the tool from the recently opened list may result in the error message "Cannot find MenuBars.xlm." To recover from this error, click the [OK] button. A Macro Error Dialog Box appears. Click the [Halt] button. Then select Quit from the File Menu.

3.1 INSTRUCTIONS FOR THE MACINTOSH VERSION OF THE REUSE ECONOMICS SPREADSHEET MODEL TOOL

3.1.1 Recommended Configuration

The recommended configuration for running the Macintosh version of the Reuse Economics Spreadsheet Model tool is:

- A Macintosh capable of running Microsoft Excel, version 4.0
- 4 megabytes of RAM
- Macintosh system software, version 6.0.2 or later
- Finder, version 6.1 or later
- Microsoft Excel, version 4.0
- Enough space on the hard disk for the Reuse Economics Spreadsheet Model files (758 kilobytes)

3.1.2 Installing the Software on a Hard Disk

To copy the contents of the diskette to your hard disk, perform the following steps:

- Place the diskette containing the Reuse Economics Spreadsheet Model tool in the disk drive.
- Open the diskette by double-clicking on the diskette icon.
- Copy the RESSM folder by clicking on the folder icon and dragging it to the hard drive icon. Release the mouse button to start the copy procedure. The contents of the folder are placed in a folder named RESSM.

3.1.3 Running the Reuse Economics Spreadsheet Model Tool

3.1.3.1 Invoking the Reuse Economics Spreadsheet Model Tool From a Diskette

To invoke the Reuse Economics Spreadsheet Model tool from a diskette, perform the following steps:

- Make sure you have read-write access to the diskette.
- Place the diskette containing the Reuse Economics Spreadsheet Model tool in the disk drive.
- Open the diskette by double-clicking on the diskette icon. A window displaying the diskette contents appears.
- Open the RESSM folder by double-clicking on the folder icon. A window displaying the folder contents appears.
- Start the RESSM application by double-clicking on the file RESSMBgn.xlm. The Reuse Economics Spreadsheet Model tool Start window appears.

3.1.3.2 Invoking the Reuse Economics Spreadsheet Model Tool From a Hard Disk

To invoke the Reuse Economics Spreadsheet Model tool from a hard disk, perform the following steps:

- Open the hard drive by double-clicking on the hard drive icon. A window displaying the hard drive contents appears.
- Open the RESSM folder by double-clicking on the folder icon. A window displaying the folder contents appears.
- Start the RESSM application by double-clicking on the file RESSMBgn.xlm. The Reuse Economics Spreadsheet Model tool Start window appears.

Operation of the tool is described in Section 4.

3.2 INSTRUCTIONS FOR THE PC VERSION OF THE REUSE ECONOMICS SPREADSHEET MODEL TOOL

3.2.1 Recommended Configuration

The recommended configuration for running the PC version of Reuse Economics Spreadsheet Model tool is:

- An IBM-compatible PC capable of running Microsoft Excel, version 4.0
- 4 megabytes of RAM
- MS-DOS, version 3.3 or greater
- Microsoft Windows, version 3.0 or greater

- Microsoft Excel, version 4.0
- Enough space on the hard disk for the Reuse Economics Spreadsheet Model files (821 kilobytes)

3.2.2 Installing the Software on a Hard Disk

To copy the contents of the diskette to your hard disk, perform the following steps:

- Create a subdirectory under the Excel directory (C > mkdir \excel\ressm).
- Copy all files from the diskette to the RESSM directory you created.

  Note: You should not place the files in a separate subdirectory from the Microsoft Excel files.
- From the Program Manager Menu, select the program group in which to place RESSM and then select the File and New options. A property sheet appears.
- Verify that you have selected the program item and then click the [OK] button. The Program Item Properties dialog box appears.
- In the Description field, type RESSM, then press the <TAB> key or move the mouse to the command line field.
- In the Command line field, type C:\excel\ressm\ressmbgn.xlm and press <RETURN> or click the [OK] button.
- In the working directory field, type C:\excel\ressm.
- If you would like to replace the icon, select the [Change Icon] button before you click the [OK] button or press <RETURN>. Then enter the full path name containing the icon file. If you do not want to change your icon and accept the default icon, click the [OK] button.

Installation of the Reuse Economics Spreadsheet Model tool on your hard disk is now complete.

3.2.3 Running the Reuse Economics Spreadsheet Model Tool

3.2.3.1 Invoking the Reuse Economics Spreadsheet Model Tool From a Diskette

To invoke the Reuse Economics Spreadsheet Model tool from a diskette, perform the following steps:

- Make sure you have read-write access to the diskette.
- Double-click on the Microsoft Excel icon to start Microsoft Excel.
- Select the File and Open options.
- In the directories list box, select the drive where you have inserted the floppy and click the [OK] button. The files contained on the floppy now display in the files list box.
- Select RESSMBGN.XLM and click the [OK] button. The software loads and the opening screen displays with the File and Modes pull-down menus.

Operation of the tool is described in Section 4.

3.2.3.2 Invoking the Reuse Economics Spreadsheet Model Tool From a Hard Disk

To invoke the Reuse Economics Spreadsheet Model tool from a hard disk, double-click the RESSM icon. The software loads, and the opening screen displays with the File and Modes pull-down menus.

Operation of the tool is described in Section 4.

3.3 LIST OF FILES INCLUDED IN THE MACINTOSH VERSION OF THE REUSE ECONOMICS SPREADSHEET MODEL TOOL

CompCOM	M1aExt4.xls	M3Form.xlm	Mode2DB.xls
CompISP	M1aExt5.xls	M3Grafs.xlm	Mode3.xlw
CompNiSS	M1aForm.xlm	M4Form.xlm	Mode3DB.xls
CompSSi	M1aGrafs.xlm	MenuBars.xlm	Mode4.xlw
CompST1	M1bForm.xlm	Mode1a.xlw	Mode4DB.xls
CompSTi	M2Ext1.xls	Mode1aDB.xls	RESSMBgn.xlm
M1aExt1.xls	M2Form.xlm	Mode1b.xlw	RESSMLog.xls
M1aExt2.xls	M2Grafs.xlm	Mode1bDB.xls	RESSMLog.xlw
M1aExt3.xls	M3Ext1.xls	Mode2.xlw	

3.4 LIST OF FILES INCLUDED IN THE PC VERSION OF THE REUSE ECONOMICS SPREADSHEET MODEL TOOL

COMPCOM.DLL	M1AEXT4.XLS	M3FORM.XLM	MODE2DB.XLS
COMPISP.DLL	M1AEXT5.XLS	M3GRAFS.XLM	MODE3.XLW
COMPNISS.DLL	M1AFORM.XLM	M4FORM.XLM	MODE3DB.XLS
COMPSSI.DLL	M1AGRAFS.XLM	MENUBARS.XLM	MODE4.XLW
COMPST1.DLL	M1BFORM.XLM	MODE1A.XLW	MODE4DB.XLS
COMPSTI.DLL	M2EXT1.XLS	MODE1ADB.XLS	RESSMBGN.XLM
M1AEXT1.XLS	M2FORM.XLM	MODE1B.XLW	RESSMLOG.XLS
M1AEXT2.XLS	M2GRAFS.XLM	MODE1BDB.XLS	RESSMLOG.XLW
M1AEXT3.XLS	M3EXT1.XLS	MODE2.XLW	

4. OPERATING THE TOOL

4.1 USER INTERFACE CONVENTIONS

The Reuse Economics Spreadsheet Model tool uses standard Microsoft Excel interface conventions whenever possible. The tool provides custom menus to protect you from inadvertently modifying the application. It also provides a user-friendly interface to those not well versed in using Microsoft Excel. For more detailed information about standard Microsoft Excel interface conventions, please refer to the *Microsoft Excel User's Guide* (Microsoft 1991).

NOTE: Due to the incompatibility between this and previous versions of the tool, any existing data from previous versions will need to be reentered for use in version 3.

This section provides a brief description of the user interface conventions that the tool uses. It also provides examples of using the tool, including creating graphs of data that you provide and that the tool calculates.

Figure 4-1 provides a menu hierarchy for the Reuse Economics Spreadsheet Model tool's available functionality.

4.1.1 SELECTING FROM MENUS

Make a menu selection by holding down the mouse button and dragging the mouse over the menu selections until you highlight your desired choice. Release the mouse button on the selected option to execute your choice.

4.1.2 ACTIVATING A WINDOW

Activate a window by clicking the mouse anywhere in the window. The title bar of a window contains stripes when that window is active.

4.1.3 MENU BARS AND ACTIVE WINDOWS

The menu bar displayed corresponds to the appropriate type of menu bar for the active window. The striped title bar indicates the active window.

4.1.4 CLOSING THE ACTIVE WINDOW

Close the active window by clicking the mouse button on the Close box in the upper left corner of the window or choose the Close operation from the File menu (see Sections 4.4.1, 4.5.1, and 4.6.1).

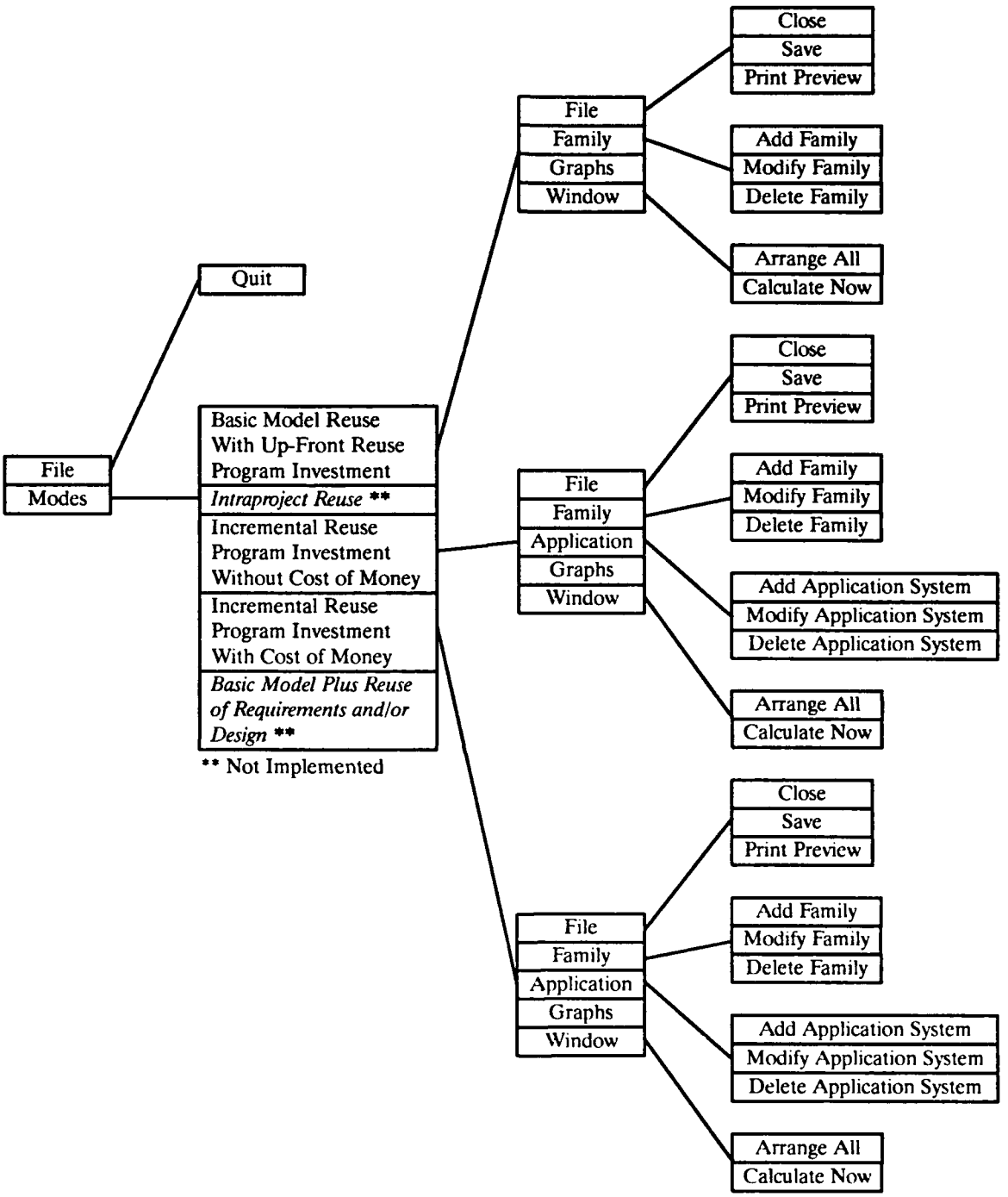


Figure 4-1. Reuse Economics Spreadsheet Model Menu Hierarchy

4.1.5 Sizing the Active Window

Use standard mouse techniques to size and move windows. To change the size of a window, select a corner edge and drag the mouse to the desired location. To move a window, select a noncorner portion of a window and drag the mouse to the desired location.

4.1.6 Scrolling the Active Window

The tool provides both horizontal and vertical scroll bars to scroll windows.

4.2 THE START WINDOW

The Start window appears when you start the system (see Figure 4-2). It provides access to the Main window.

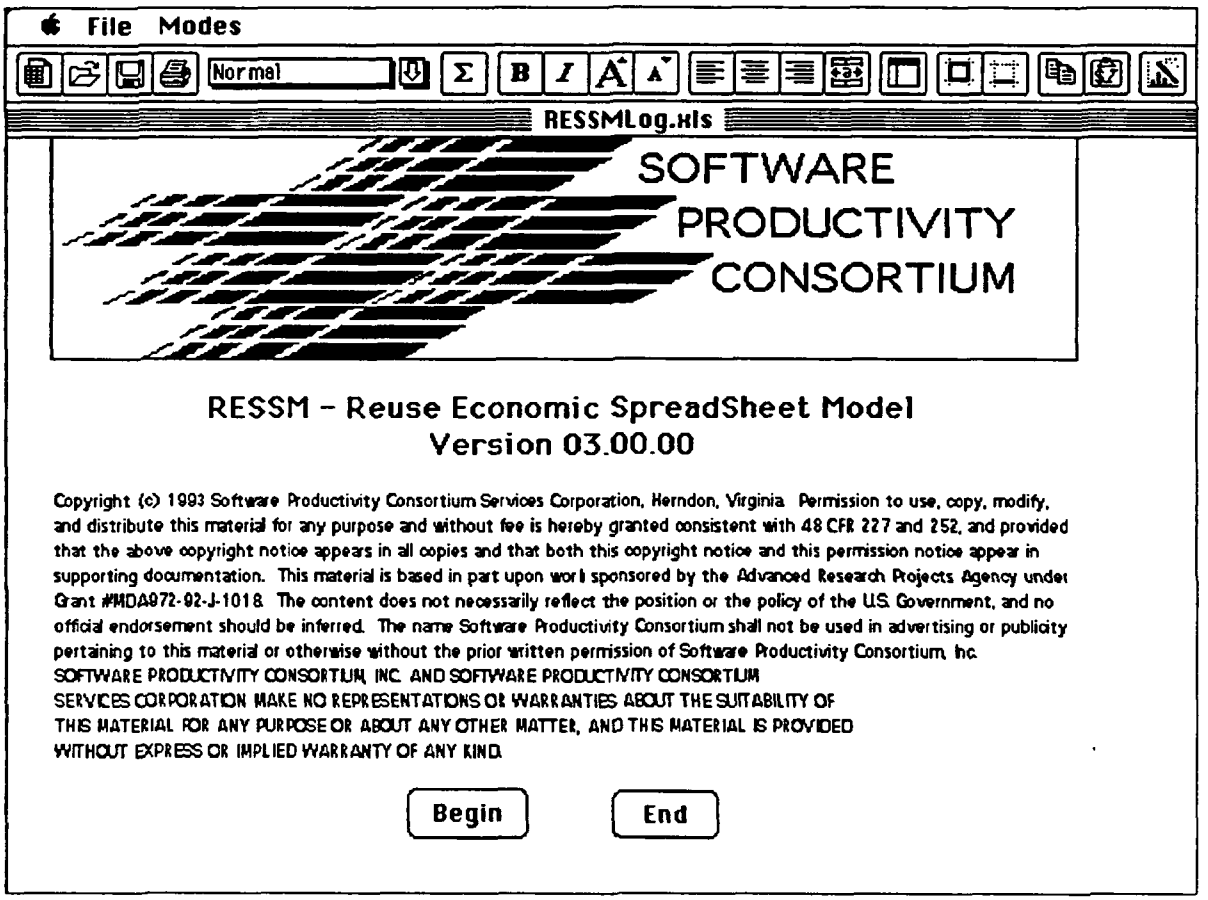


Figure 4-2. Start Window

The Start window consists of three parts: a static text area, two buttons, and a custom Microsoft Excel menu bar. The static text area displays the Consortium logo and the tool name. The [Begin] and [End] buttons are used to start or stop the tool:

- Clicking the [Begin] button causes the Main window to be displayed.
- Clicking the [End] button terminates the tool.

The menu bar contains two menus named File and Modes. The menu bar entries are disabled in the Start window. They become enabled in the Main window.

4.3 THE MAIN WINDOW

The Main window is the window that appears after clicking the [Begin] button on the Start window (see Figure 4-3). It provides access to all system functions.

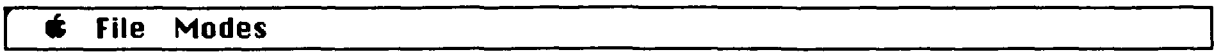


Figure 4-3. Main Window

The Main window consists of a custom Microsoft Excel menu bar. The menu bar contains three menus named File, Modes, and Window.

4.3.1 The File Menu

The File menu allows you to exit the system. To exit, select Quit from the File menu. Quit exits both the application and Microsoft Excel.

4.3.2 The Modes Menu

The Modes menu allows you to choose one of the following modes of operation defined for the tool:

- Mode 1a: Basic Model—Reuse With Up-Front Reuse Program Investment
- Mode 1b: Intraproject Reuse
- Mode 2: Incremental Reuse Program Investment Without Cost of Money
- Mode 3: Incremental Reuse Program Investment With Cost of Money
- Mode 4: Basic Model Plus Reuse of Requirements and/or Design

To choose a reuse model, select one of the modes listed in the Modes menu. This version of the tool supports only Modes 1a, 2, and 3.

- Selecting Basic Model—Reuse With Up-Front Reuse Program Investment results in the presentation of the Mode 1a window. This mode assumes that all of the application systems that make up a family have the same parameter values for Proportion of Code Reuse, Unit Cost of Reuse Program Investment, Unit Cost of New Code, Unit Cost of Reused Code, Size of Reuse Library, Average Size of Application System, and Relative Library Capacity. The model implements each family as a single row of the Mode 1a worksheet.

- Selecting Incremental Reuse Program Investment Without Cost of Money results in the presentation of the Mode 2 window. This mode assumes that each of the application systems that make up a family may have unique parameter values for Unit Cost of New Code, Unit Cost of Reused Code, Size of Reuse Library, and Size of Application System. The model implements each family as a contiguous group of rows of the Mode 2 worksheet. All of the rows of a family are identified by a common family number.

- Selecting Incremental Reuse Program Investment With Cost of Money results in the presentation of the Mode 3 window. This mode assumes that each of the application systems that make up a family may have unique parameter values for Unit Cost of New Code, Unit Cost of Reused Code, Size of Reuse Library, and Size of Application System. The model implements each family as a contiguous group of rows of the Mode 3 worksheet. All of the rows of a family are identified by a common family number.

The names of the two other modes appear in dimmed video, and you cannot select them.

4.3.3 The Window Menu

The Window menu provides the Arrange All option, which allows you to simultaneously display all open windows. This is useful for viewing multiple graphs at the same time. A sample display resulting from invoking the Arrange All menu selection is shown in Figure 4-4.

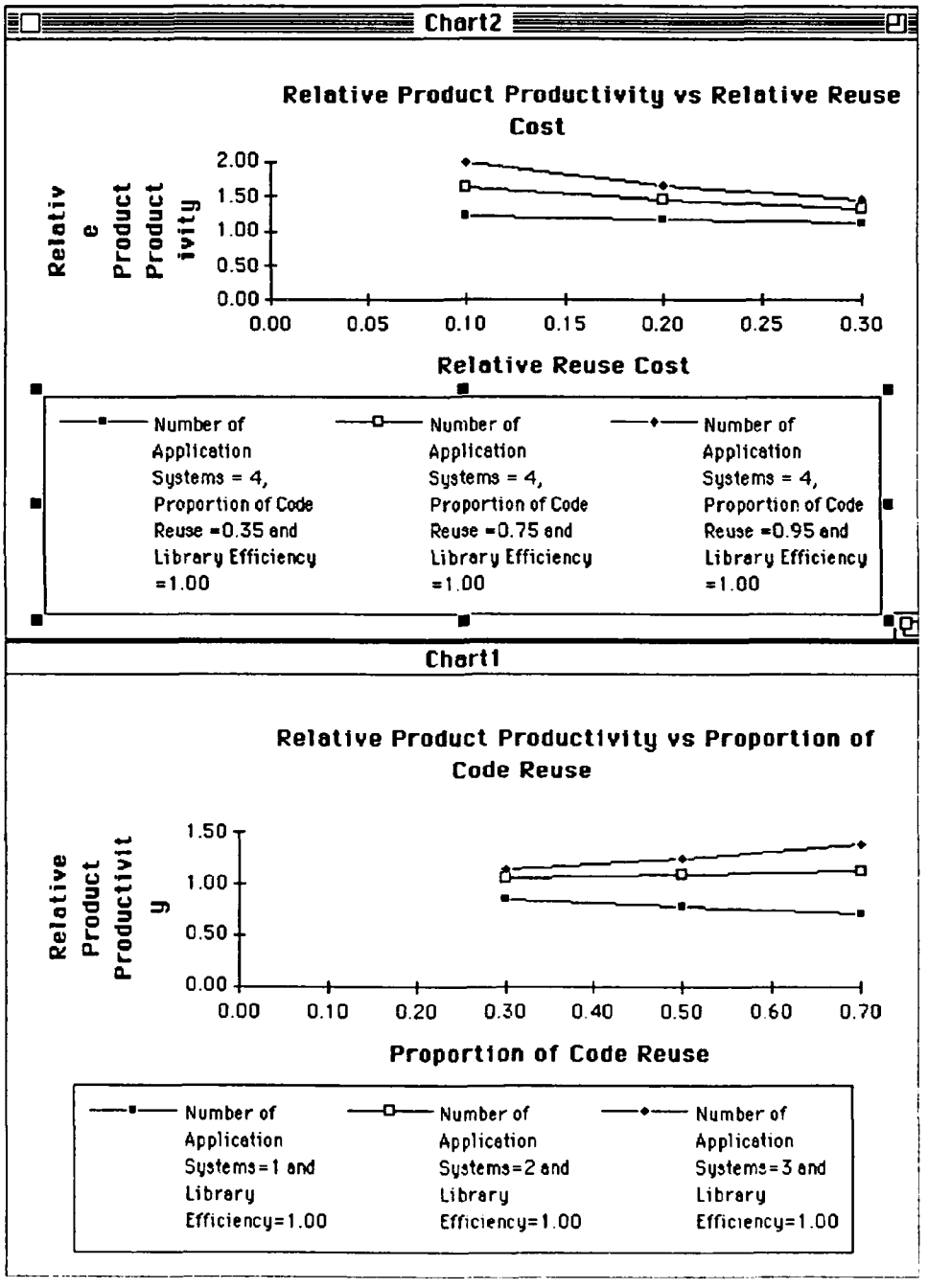


Figure 4-4. Arrange All Window

4.4 THE MODE 1a WINDOW

The Mode 1a window appears when you select Basic Model—Reuse Program Investment With Up-Front Reuse Program Investment from the Modes menu of the Main window. It provides access to all other system functions for Mode 1a operation. The window consists of a custom menu bar and a Microsoft Excel worksheet (see Figures 4-5, 4-6, and 4-7). The menu bar contains the File, Family, Graphs, and Window menus.

The worksheet contains the rows of data that either you entered or were computed from the values you entered. Each column of data corresponds to a variable described in the reuse economics model detailed in Cruickshank and Gaffney (1991) and summarized in Appendix A. Table 4-1 shows the mapping of column names to variable names.

NOTE: The sample data sets are for demonstration purposes only; you should build your own.

4.4.1 THE FILE MENU

The File menu provides the following options:

- Print Preview
  - To print the worksheet, select Print Preview from the File menu. The standard Microsoft Excel Print Preview window then appears.

NOTE: Attempting to print when there is no printer connected may result in a macro error. Should this happen, click the mouse on the [Halt] button to return to normal operation.

File Family Graphs Window

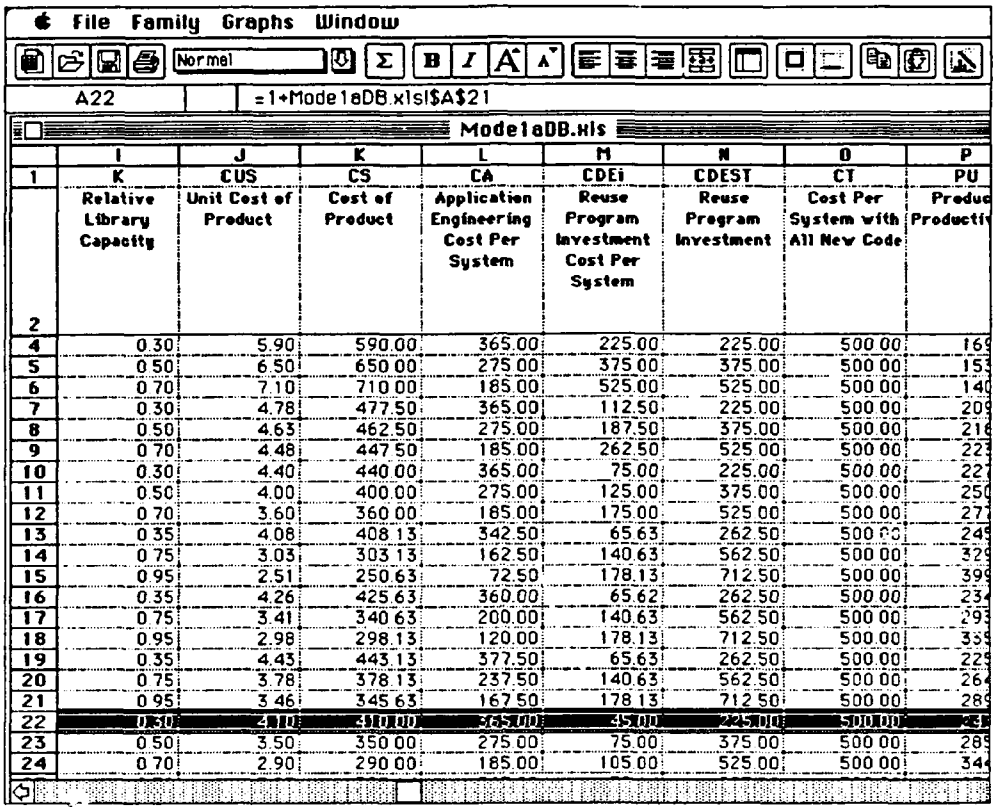
Normal

A22 =1+Mode1aDB.xls!$A$21

Mode1aDB.xls

	A	B	C	D	E	F	G	H
1	FamilyNo	N	R	CDE	CVN	CVR	ST	SS
2	Family Number	Number of Application Systems	Proportion of Code Reuse	Unit Cost of Reuse Program Investment	Unit Cost of New Code	Unit Cost of Reused Code	Size of Reuse Library	Average S of Applicat Systen
4	1	1	0.30	7.50	5.00	0.50	30.00	100
5	2	1	0.50	7.50	5.00	0.50	50.00	100
6	3	1	0.70	7.50	5.00	0.50	70.00	100
7	4	2	0.30	7.50	5.00	0.50	30.00	100
8	5	2	0.50	7.50	5.00	0.50	50.00	100
9	6	2	0.70	7.50	5.00	0.50	70.00	100
10	7	3	0.30	7.50	5.00	0.50	30.00	100
11	8	3	0.50	7.50	5.00	0.50	50.00	100
12	9	3	0.70	7.50	5.00	0.50	70.00	100
13	10	4	0.35	7.50	5.00	0.50	35.00	100
14	11	4	0.75	7.50	5.00	0.50	75.00	100
15	12	4	0.95	7.50	5.00	0.50	95.00	100
16	13	4	0.35	7.50	5.00	1.00	35.00	100
17	14	4	0.75	7.50	5.00	1.00	75.00	100
18	15	4	0.95	7.50	5.00	1.00	95.00	100
19	16	4	0.35	7.50	5.00	1.50	35.00	100
20	17	4	0.75	7.50	5.00	1.50	75.00	100
21	18	4	0.95	7.50	5.00	1.50	95.00	100
22	19	5	0.30	7.50	5.00	0.50	30.00	100
23	20	5	0.50	7.50	5.00	0.50	50.00	100
24	21	5	0.70	7.50	5.00	0.50	70.00	100

Figure 4-5. Mode 1a Window (part 1)



File Family Graphs Window

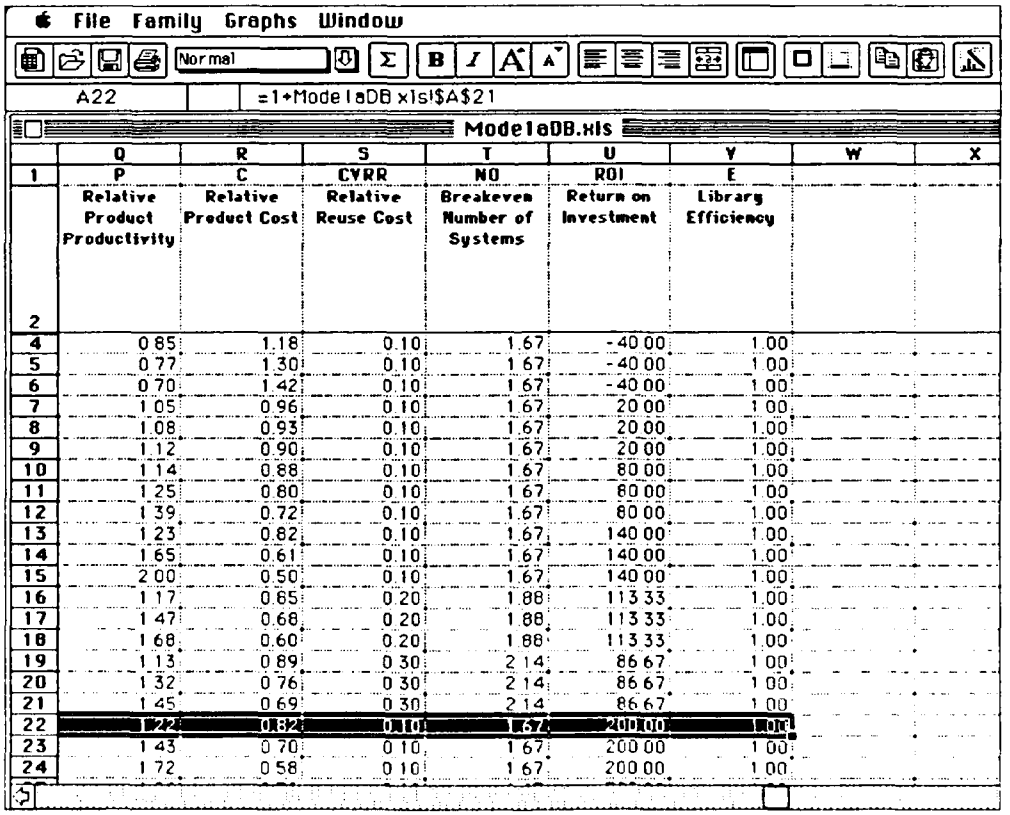
Normal

A22 =1+Mode1aDB.xls!$A$21

Mode1aDB.xls

	I	J	K	L	M	N	O	P
1	K	CUS	CS	CA	CDEi	CDEST	CT	PU
2	Relative Library Capacity	Unit Cost of Product	Cost of Product	Application Engineering Cost Per System	Reuse Program Investment Cost Per System	Reuse Program Investment	Cost Per System with All New Code	Produc Productiv
4	0.30	5.90	590.00	365.00	225.00	225.00	500.00	169
5	0.50	6.50	650.00	275.00	375.00	375.00	500.00	153
6	0.70	7.10	710.00	185.00	525.00	525.00	500.00	140
7	0.30	4.78	477.50	365.00	112.50	225.00	500.00	209
8	0.50	4.63	462.50	275.00	187.50	375.00	500.00	216
9	0.70	4.48	447.50	185.00	262.50	525.00	500.00	223
10	0.30	4.40	440.00	365.00	75.00	225.00	500.00	227
11	0.50	4.00	400.00	275.00	125.00	375.00	500.00	250
12	0.70	3.60	360.00	185.00	175.00	525.00	500.00	277
13	0.35	4.08	408.13	342.50	65.63	262.50	500.00	245
14	0.75	3.03	303.13	162.50	140.63	562.50	500.00	329
15	0.95	2.51	250.63	72.50	178.13	712.50	500.00	399
16	0.35	4.26	425.63	360.00	65.62	262.50	500.00	234
17	0.75	3.41	340.63	200.00	140.63	562.50	500.00	293
18	0.95	2.98	298.13	120.00	178.13	712.50	500.00	335
19	0.35	4.43	443.13	377.50	65.63	262.50	500.00	225
20	0.75	3.78	378.13	237.50	140.63	562.50	500.00	264
21	0.95	3.46	345.63	167.50	178.13	712.50	500.00	289
22	0.30	4.10	410.00	365.00	45.00	225.00	500.00	243
23	0.50	3.50	350.00	275.00	75.00	375.00	500.00	285
24	0.70	2.90	290.00	185.00	105.00	525.00	500.00	344

Figure 4-6. Mode 1a Window (part 2)



File Family Graphs Window

Normal

A22 =1+Mode1aDB.xls!$A$21

Mode1aDB.xls

	Q	R	S	T	U	Y	W	X
1	P	C	CYRR	NO	ROI	E		
2	Relative Product Productivity	Relative Product Cost	Relative Reuse Cost	Breakeven Number of Systems	Return on Investment	Library Efficiency		
4	0.85	1.18	0.10	1.67	-40.00	1.00		
5	0.77	1.30	0.10	1.67	-40.00	1.00		
6	0.70	1.42	0.10	1.67	-40.00	1.00		
7	1.05	0.96	0.10	1.67	20.00	1.00		
8	1.08	0.93	0.10	1.67	20.00	1.00		
9	1.12	0.90	0.10	1.67	20.00	1.00		
10	1.14	0.88	0.10	1.67	80.00	1.00		
11	1.25	0.80	0.10	1.67	80.00	1.00		
12	1.39	0.72	0.10	1.67	80.00	1.00		
13	1.23	0.82	0.10	1.67	140.00	1.00		
14	1.65	0.61	0.10	1.67	140.00	1.00		
15	2.00	0.50	0.10	1.67	140.00	1.00		
16	1.17	0.85	0.20	1.88	113.33	1.00		
17	1.47	0.68	0.20	1.88	113.33	1.00		
18	1.68	0.60	0.20	1.88	113.33	1.00		
19	1.13	0.89	0.30	2.14	86.67	1.00		
20	1.32	0.76	0.30	2.14	86.67	1.00		
21	1.45	0.69	0.30	2.14	86.67	1.00		
22	1.22	0.82	0.10	1.67	200.00	1.00		
23	1.43	0.70	0.10	1.67	200.00	1.00		
24	1.72	0.58	0.10	1.67	200.00	1.00		

Figure 4-7. Mode 1a Window (part 3)

Table 4-1. Mapping of Worksheet Column Names to Reuse Economic Model Variable Names

Worksheet Column Label	Worksheet Column Name	Variable Name*	Constraints
A	Family Number	FamilyNo	$0 < \text{FamilyNo}$
B	Number of Application Systems	N	$0 < N$
C	Proportion of Code Reuse	R	$0 \leq R \leq 1$
D	Unit Cost of Reuse Program Investment	C_{DE}	$0 < C_{DE}$
E	Unit Cost of New Code	C_{VN}	$0 < C_{VN}$
F	Unit Cost of Reused Code	C_{VR}	$0 < C_{VR}$
G	Size of Reuse Library	ST	$0 \leq ST \leq SS$
H	Average Size of Application System	SS	$0 < SS$
I	Relative Library Capacity	K	$K = ST/SS$
J	Unit Cost of Product	C_{USi}	$C_{US} = [(C_{DE}/N)\cdot K] + C_{VN} - [(C_{VN} - C_{VR})\cdot R]$
K	Cost of Product	C_S	$C_S = C_{US} \cdot SS$
L	Application Engineering Cost per System	C_{Ai}	$C_A = [C_{VN} - (C_{VN} - C_{VR})\cdot R]\cdot SS$
M	Reuse Program Investment Cost per System	C_{DEi}SumTerms1	$C_{US} \cdot SS - C_A$
N	Reuse Program Investment	C_{DEi}ST	$C_{DE}ST = C_{DE} \cdot ST$
O	Cost per System With All New Code	CT	$CT = C_{VN} \cdot SS$
P	Product Productivity	PU	$PU = 1,000/C_{US}$
Q	Relative Product Productivity	P	$P = C_{VN}/C_{US}$
R	Relative Product Cost	C	$C = 1/P$
S	Relative Reuse Cost	C_{VRR}	$C_{VRR} = C_{VR}/C_{VN}$
T	Breakeven Number of Systems	N_0	$N_0 = C_{DE}/[(C_{VN} - C_{VR})\cdot E]$
U	Return on Investment	ROI	$ROI = ((N/N_0) - 1)\cdot 100$
V	Library Efficiency	E	$E = R/K$

* Appendix A and Cruickshank and Gaffney (1991) use subscripts on some of these variables, such as C_{DE} instead of CDE and C_{US} instead of CUS.

- Save
  - To save changes made to the worksheet, select Save from the File menu. The tool saves the data and returns you to the Mode 1a window. Saving a worksheet overwrites the previous data with the current data. The tool maintains only one version of the worksheet and makes it accessible through the application.
  - To retain old data indefinitely, make a copy of the file Mode1aDB.xls under a new name. Do this outside of the Reuse Economics Spreadsheet Model tool.
  - To restore old data, rename a saved file to Mode1aDB.xls. You should be able to print a saved worksheet from Microsoft Excel. Saving old data under different file names is a way to preserve historical data associated with a particular graph or set of graphs.
- Close
  - To exit the Mode 1a window, select Close from the File menu. A dialog box appears to warn you if you have any unsaved changes. Click the [Yes] or [No] button, as appropriate, to continue the Close process.
  - When the Close process completes, the Main window appears.

4.4.2 Dialog Box Description

The Family menu operations use a common dialog box interface. The interface for Modify operations consists of a sequence of two dialog boxes. The interface for Add and Delete operations consists of a single dialog box that is identical to the second dialog box displayed for a Modify operation.

The first dialog box contains a check box for each of the modifiable fields. It allows you to specify which fields you wish to modify, thus providing protection against inadvertent data modification. You must select the check boxes for those fields that you wish to modify. Clicking the [OK] button causes the next dialog box in the sequence to be displayed. Clicking the [Cancel] button terminates the current operation and returns control to the Mode 1a window.

The second dialog box contains list boxes and number edit boxes. It allows you to enter data and display data corresponding to a selected family. The fields of the dialog box are enabled or disabled in accordance with the type of operation to be performed. A list box is used for selecting family numbers. The enabled number edit boxes are used for entering data for the selected family. The disabled number edit boxes are used to display constraints or current data values for your convenience. Clicking the [Refresh] button updates the screen to display the dialog box with the current values for the selected family shown in the number edit boxes. Clicking the [Accept] button carries out the current operation and returns control to the dialog box. Clicking the [Cancel] button terminates the current operation and returns control to the Mode 1a window.

The fields that are modifiable include:

- *N.* This field corresponds to the Number of Application Systems in the family.
- *R.* This field corresponds to the Proportion of Code Reuse for all members of the family.

- ***CDE.*** This field corresponds to the Unit Cost of Reuse Program Investment. All applications within a family have the same value for CDE. Due to an implementation constraint that requires a nonzero value for CDE, it is not possible to exactly model the situation where there is no Reuse Program Investment (i.e., you are reusing library components that have been supplied to you at no cost). However, you can approximately model that situation by supplying a small value (e.g., 0.001) for CDE. This may cause the Return on Investment field to display a value too large for the column width. Such a situation is indicated by the presence of ### instead of a numeric value in the worksheet cell.

- ***CVN.*** This field corresponds to the Unit Cost of New Code. All applications within a family have the same value for CVN.

- ***CVR.*** This field corresponds to the Unit Cost of Reused Code. All applications within a family have the same value for CVR.

- ***ST.*** This field corresponds to the Size of Reuse Library.

- ***SS.*** This field corresponds to the Average Size of the Application Systems in the family.

4.4.3 The Family Menu

The Family menu provides the following options:

- Add Family
  - To add a family:
    - -- Select Add Family from the Family menu. The Add Family Dialog Box then appears as shown in Figure 4-8.
    - -- Enter parameter values in the fields provided. You can use the <TAB> key to sequentially traverse the data entry fields or use the mouse to point and click on the fields directly.
    - -- Click the [Accept] button when you are finished modifying data. The new row will be added to the end of the existing worksheet data. The row will be identified by a Family Number and will have the values specified for the input fields.
  - To view an existing family, select the desired Family Number from the Family Number list box, and click the [Refresh] button. The data for the selected family will be shown in the corresponding dialog box fields.
  - Clicking the [Cancel] button will terminate the Add Family operation and return control to the Mode 1a window.

    Note: Pressing <RETURN> is the same as clicking the [Refresh] button.

Example: To create a family with parameter values N = 5, R = 0.3, CDE = 7.5, CVN = 5, CVR = 0.5, ST = 30, and SS = 100:

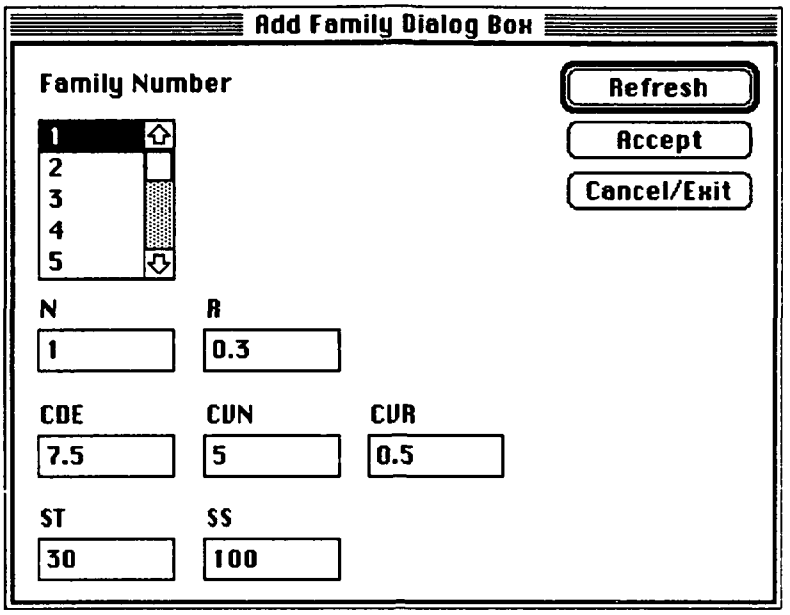


Figure 4-8. Mode 1a—Add Family Dialog Box

1. Select Add Family from the Family menu to display the Add Family Dialog Box.
2. If there is an existing family with similar parameter values, select the existing family number and click the [Refresh] button to display the parameter values for that family. Then modify the parameters to the appropriate values for the new family. If the dialog box contains the data as displayed in Figure 4-8, then you need only change the value for N from 1 to 5 because all of the other values are correct.
3. If there is no existing family with similar parameter values, just modify the displayed parameter values that need to be changed for the new family.
4. Click the [Accept] button to create the new family.
5. Click the [Cancel] button to terminate the Add Family operation.

- Modify Family
  - To modify a family:
    - Select Modify Family from the Family menu. The Modify Family Dialog Box1 then appears as shown in Figure 4-9.
    - Select the check boxes corresponding to those values that are to be modified.
    - Click the [OK] button to proceed to the Modify Family Dialog Box2 as shown in Figure 4-10. The Modify Family Dialog Box2 provides the means to modify a row representing a family.
    - Select the corresponding Family Number by clicking the mouse button to highlight the number in the Family Number list box of the Modify Family Dialog Box2. Then enter those values that you wish to modify.

— Clicking the [Accept] button will modify the selected family and return control to the Modify Family Dialog Box2.

- Clicking the [Refresh] button will update the dialog box to display the current values for the selected family.

- Clicking the [Cancel] button will terminate the Modify Family operation and return control to the Mode 1a window.

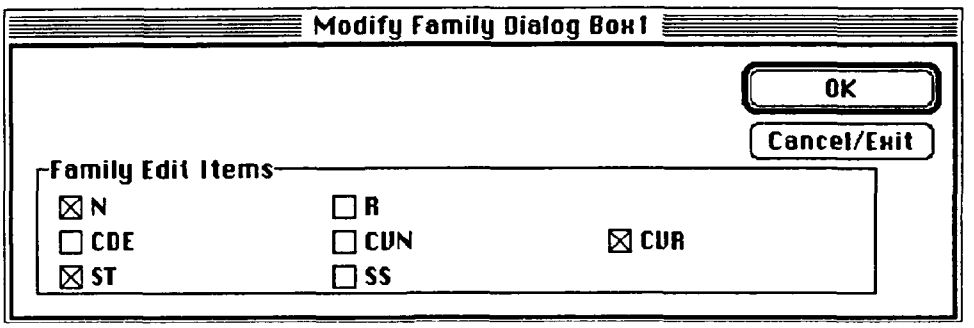


Figure 4-9. Mode 1a—Modify Family Dialog Box1

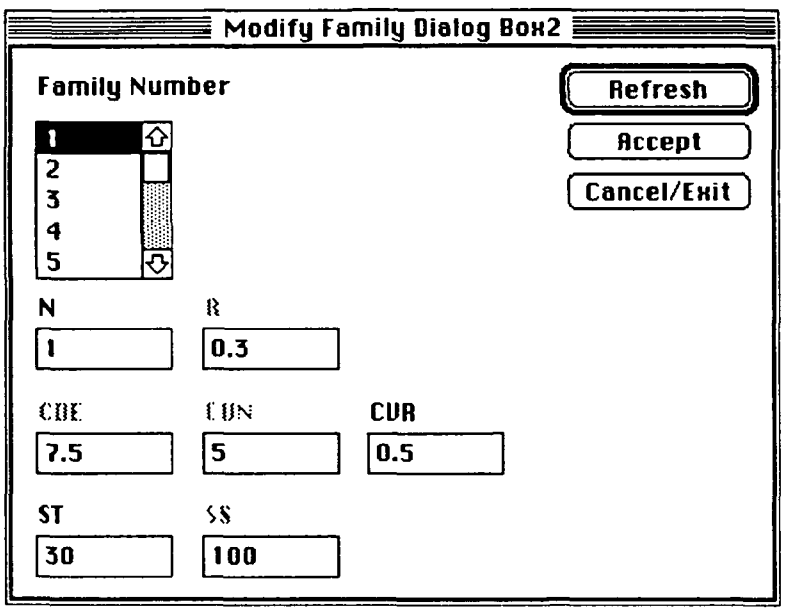


Figure 4-10. Mode 1a—Modify Family Dialog Box2

EXAMPLE: To modify a family to set parameters N = 6, CVR = 1.5, and ST = 50:

1. Select Modify Family from the Family menu to display the Modify Family Dialog Box1.

2. Select the check boxes for N, CVR, and ST (as shown in Figure 4-9). Make sure the check boxes for nonmodifiable fields are deselected.

3. Click the [OK] button to proceed to the Modify Family Dialog Box2 (as shown in Figure 4-10).

4. Select the Family Number for the family that you wish to modify.

5. Click the [Refresh] button to display the parameter values for the selected family.
6. Enter the new values for N, CVR, and ST in the appropriate fields.
7. Click the [Accept] button to modify the selected family.
8. Click the [Cancel] button to terminate the Modify Family operation.

- Delete Family
  - To delete a family:
    - — Select Delete Family from the Family menu. The Delete Family Dialog Box then appears as shown in Figure 4-11.
    - — Select the corresponding Family Number by clicking the mouse button to highlight the number in the Family Number list box.
    - — Clicking the [Accept] button will cause the Delete Confirmation Dialog Box to be displayed (see Figure 4-12).
    - — Click the [OK] button if you wish to proceed with the delete operation. The row of the selected family will be deleted and the remaining worksheet data will be renumbered to reflect the number of different families represented in the worksheet. Click the [Cancel] button if you wish to abort the delete operation.
  - Clicking the [Refresh] button will update the dialog box with the current values for the selected family.
  - Clicking the [Cancel] button will terminate the Delete Family operation and return control to the Mode 1a window.

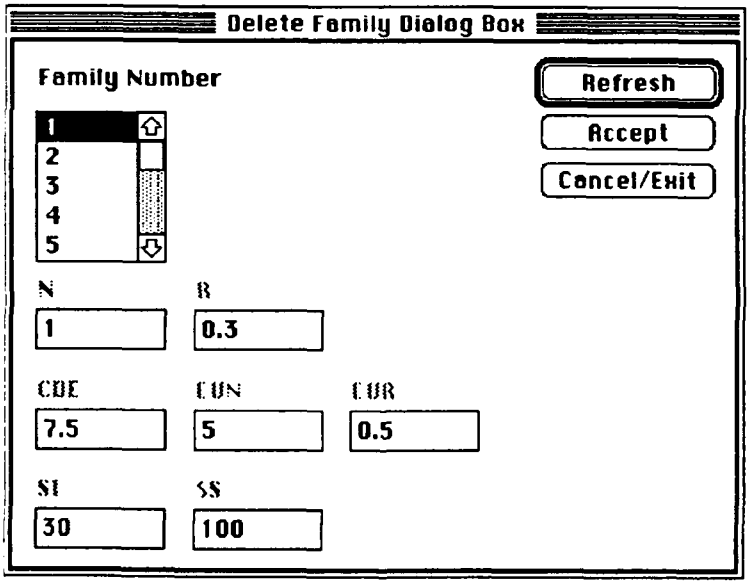


Figure 4-11. Mode 1a—Delete Family Dialog Box

EXAMPLE: To delete a family:

1. Select Delete Family from the Family menu to display the Delete Family Dialog Box (as shown in Figure 4-11).

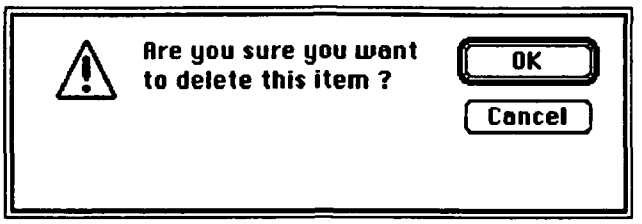


Figure 4-12. Delete Confirmation Dialog Box

2. Select the Family Number for the family that you wish to delete.

3. Click the [Refresh] button to display the parameter values for the selected family (just to make sure that you have selected the correct family).

4. Click the [Accept] button to proceed to the Delete Confirmation Dialog Box (as shown in Figure 4-12).

5. Click the [OK] button in the Delete Confirmation Dialog Box to delete the selected family and display the Delete Family Dialog Box.

6. Click the [Cancel] button in the Delete Family Dialog Box to terminate the Delete Family operation.

4.4.4 The Graphs Menu

The Graphs menu generates built-in graphs for Mode 1a calculations. A series of dialog boxes appear when you select a graph from the Graphs menu. These input dialog boxes allow you to specify the options to apply to the selected graph. They are specific to each graph selection. In general, the dialog boxes request input such as the number of curves to plot and values to use as selection criteria when extracting the data to plot.

Each dialog box has option buttons or list boxes from which you select input data values. Each dialog box also has an [OK] button and a [Cancel] button. Click the [OK] button to transmit the input values to the application and continue building the graph.

Note: Pressing <RETURN> in response to a dialog box is the same as clicking the [OK] button.

Click the [Cancel] button to terminate the graph build operation. See Section NO TAG for more details about the Mode 1a graphs.

To produce a graph from the worksheet data, select the desired graph from the Graphs menu. There are five built-in graphs that you can produce in Mode 1a:

- Relative Product Productivity vs Proportion of Code Reuse
- Relative Product Productivity vs Relative Reuse Cost
- Product Productivity vs Number of Application Systems
- Return on Investment vs Number of Application Systems
- Labor Months vs Number of Application Systems

4.4.4.1 Relative Product Productivity vs Proportion of Code Reuse Graph

The Relative Product Productivity vs Proportion of Code Reuse graph provides up to three graphs of relative productivity (productivity for the development of a product consisting of both new and reused code relative to productivity using only new code) as a function of the proportion of code reused. The three graphs differ with respect to the number of uses (N) employed.

NOTE: You should ensure that all of the points plotted use the same values for the unit costs of reuse program investment (C_{DE}), new code (C_{VN}), and reusing code (C_{VR}).

One dialog box appears for entering your data (shown in Figure 4-13).

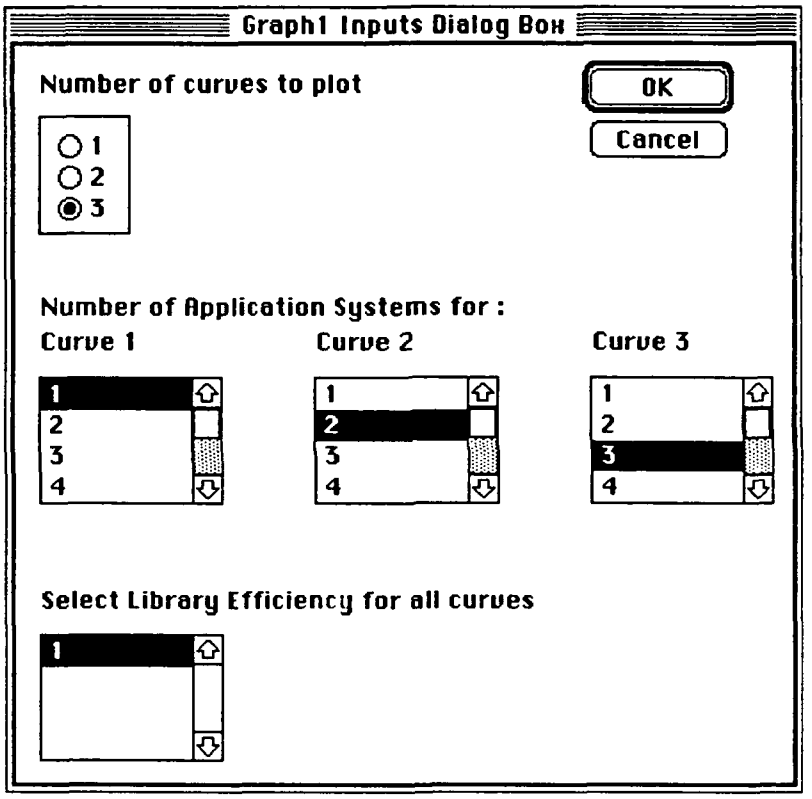


Figure 4-13. Mode 1a—Graph1 Inputs Dialog Box

The Graph1 Inputs Dialog Box requests a value for the number of curves to plot, the number of application systems for each of the curves, and the library efficiency to use in all plots.

- To specify a value for the number of curves to plot, select the appropriate option button.
- To specify the values for the number of application systems for each curve, select a value from the list box corresponding to each desired curve.
- To specify a value for the library efficiency, select a value from the corresponding list box.
- To have the selected inputs accepted by the application, click the [OK] button and the graph build operation will continue.

- Clicking the [Cancel] button will terminate the graph build operation and return control to the Mode 1a window.

NOTE: List boxes display only values that exist for the appropriate fields in the Mode1aDB.xls worksheet.

When you complete your data entries, the graph window displays the graph (see Figure 4-14).

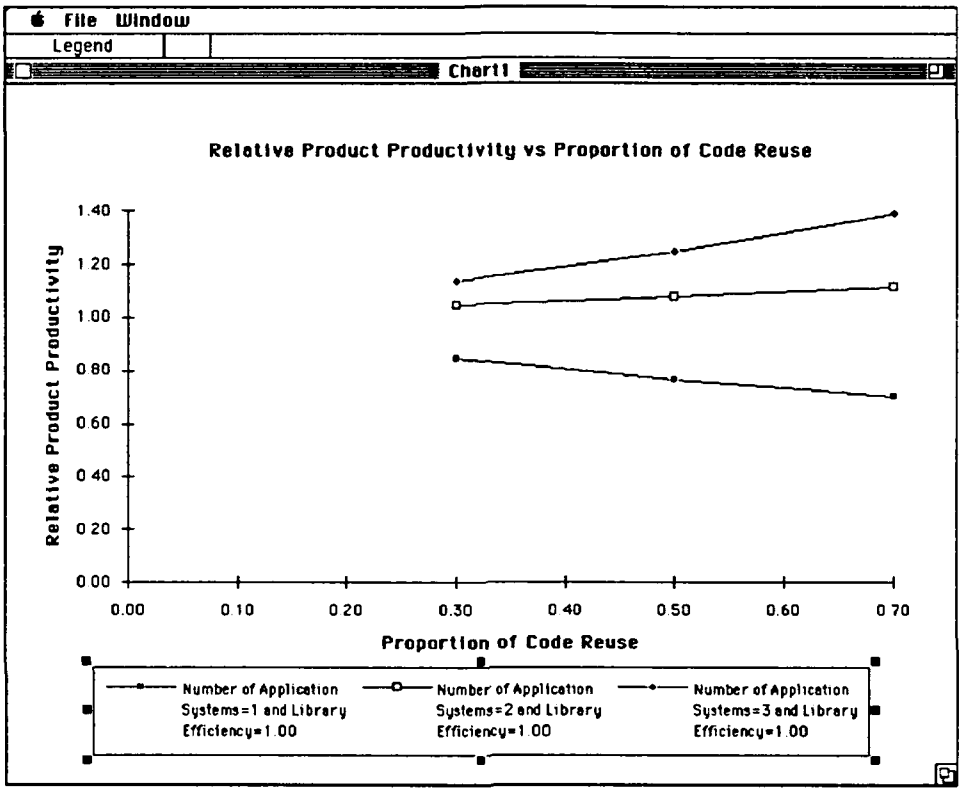


Figure 4-14. Mode 1a—Relative Product Productivity vs Proportion of Code Reuse Graph Window

Table 4-2 shows the input data values that produced the graph in Figure 4-14.

Table 4-2. Input Data Values for Relative Product Productivity vs Proportion of Code Reuse Graph Window

Number of Application Systems (N)	Proportion of Code Reuse (R)	Unit Cost of Reuse Program Investment (C_{DE})	Unit Cost of New Code (C_{VN})	Unit Cost of Reused Code (C_{VR})	Relative Library Capacity (K)
1	0.3	7.5	5	0.5	0.3
1	0.5	7.5	5	0.5	0.5
1	0.7	7.5	5	0.5	0.7
2	0.3	7.5	5	0.5	0.3
2	0.5	7.5	5	0.5	0.5
2	0.7	7.5	5	0.5	0.7
3	0.3	7.5	5	0.5	0.3
3	0.5	7.5	5	0.5	0.5
3	0.7	7.5	5	0.5	0.7

EXAMPLE: The data for each curve is selected based on the values you specify for the Number of Application Systems (N) and the Library Efficiency (E). Using the dialog box shown in Figure 4-13, the first curve will display a point for each row in the ModelaDB.xls worksheet (see Figures 4-5, 4-6, and 4-7) with N = 1 and E = 1. Similarly, the second curve will display a point for each row in the ModelaDB.xls worksheet (see Figures 4-5, 4-6, and 4-7) with N = 2 and E = 1. The data displayed in Table 4-2 shows a set of three points for each curve. The first point is represented by the rows with Proportion of Code Reuse (R) = 0.3 and Relative Library Capacity (K) = 0.3. The second point of each curve has R = 0.5 and K = 0.5. The third point of each curve has R = 0.7 and K = 0.7. In each case, you will notice that R = K. This forces the value for Library Efficiency to equal 1. Thus, we get the desired display. This graph displays the effect on Relative Product Productivity (P) of varying R as N increases (assuming that maximal reuse of code is occurring and holding other parameters constant). To generate the Relative Product Productivity vs Proportion of Code Reuse Graph for Number of Application Systems = 1, 2, and 3 with Library Efficiency = 1:

1. Scan your data to be sure that it does not contain extra rows that match your intended selection criteria but are not meant to be plotted (e.g., you might have a row with N = 1, CDE = 15, CVN = 10, CVR = 1, and E = 1, which is not comparable to the data shown above because the unit costs are not the same). If such data exists, eliminate it from selection by temporarily modifying its value for the selection criteria (e.g., you could set N = 10 to eliminate it from selection).
2. Select Relative Product Productivity vs Proportion of Code Reuse from the Graphs menu to display the Graph1 Inputs Dialog Box (as shown in Figure 4-13).
3. Select Number of curves to plot = 3.
4. Select Number of Application Systems for Curve 1 = 1.
5. Select Number of Application Systems for Curve 2 = 2.
6. Select Number of Application Systems for Curve 3 = 3.
7. Select Library Efficiency for all curves = 1.
8. Click the [OK] button in the Graph1 Inputs Dialog Box to display the graph for the selected data (as shown in Figure 4-14).

4.4.4.2 Relative Product Productivity vs Relative Reuse Cost Graph

The Relative Product Productivity vs Relative Reuse Cost graph provides up to three graphs of relative productivity (as defined earlier) as a function of the unit cost of reusing code (C_{VR}) relative to the unit cost of creating new code (C_{VN}). This relative cost, C_{VRR}, is given by the formula $C_{VRR} = C_{VR}/C_{VN}$. The three graphs differ with respect to the values of R, the proportion of code reuse, that you select.

NOTE: You should ensure that all of the points plotted use the same values for the unit costs of reuse program investment (C_{DE}) and new code (C_{VN}).

Two dialog boxes appear for entering your data (shown in Figures 4-15 and 4-16).

The Graph2A Inputs Dialog Box requests values for the number of curves to plot and the proportion of code reuse for each curve.

- To specify a value for the number of curves to plot, select the appropriate option button.

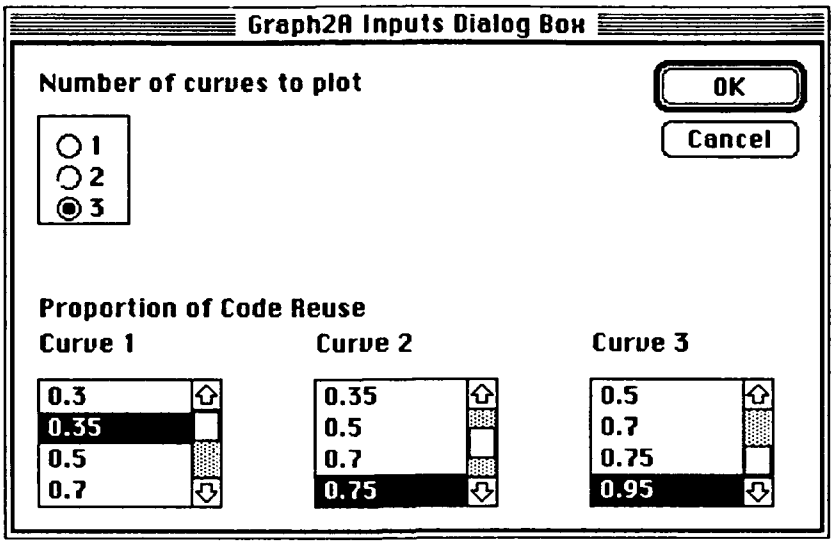


Figure 4-15. Mode 1a—Graph2A Inputs Dialog Box

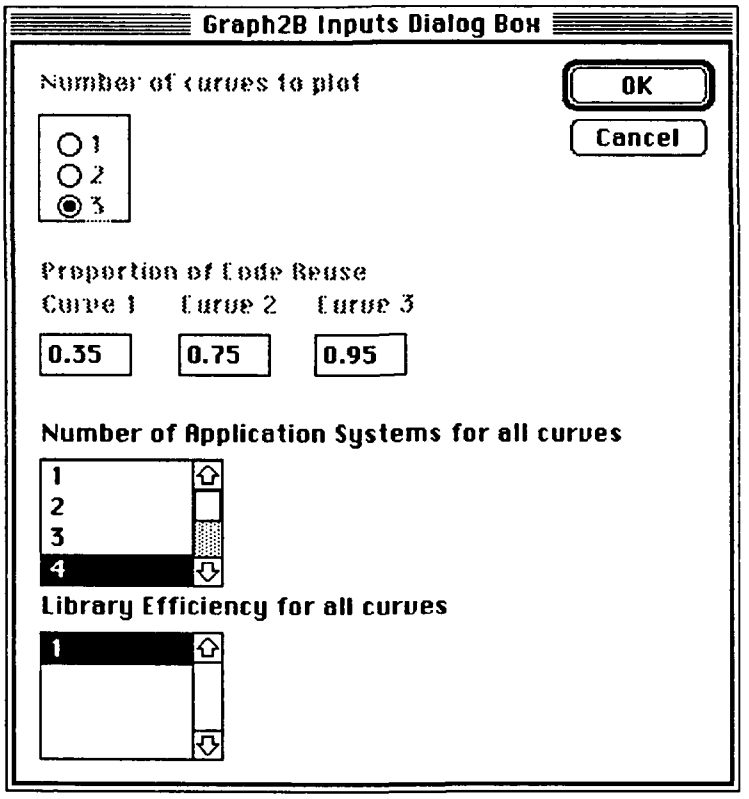


Figure 4-16. Mode 1a—Graph2B Inputs Dialog Box

- To specify the values for the proportion of code reuse for each curve, select a value from the list box corresponding to each desired curve.

- To have the selected inputs accepted by the application, click the [OK] button and the Graph2B Inputs Dialog Box will be displayed.

- Clicking the [Cancel] button will terminate the graph build operation and return control to the Mode 1a window.

The Graph2B Inputs Dialog Box displays the selected values from the Graph2A Inputs Dialog Box and requests values for the number of application systems for all curves and the library efficiency to use in all plots.

- To specify a value for the number of application systems, select a value from the corresponding list box.
- To specify a value for the library efficiency, select a value from the corresponding list box.
- To have the selected inputs accepted by the application, click the [OK] button and the graph build operation will continue.
- Clicking the [Cancel] button will terminate the graph build operation and return control to the Mode 1a window.

NOTE: List boxes display only values that exist for the appropriate fields in the Mode1aDB.xls worksheet.

When you complete your entries, the graph window displays the resultant graph (see Figure 4-17).

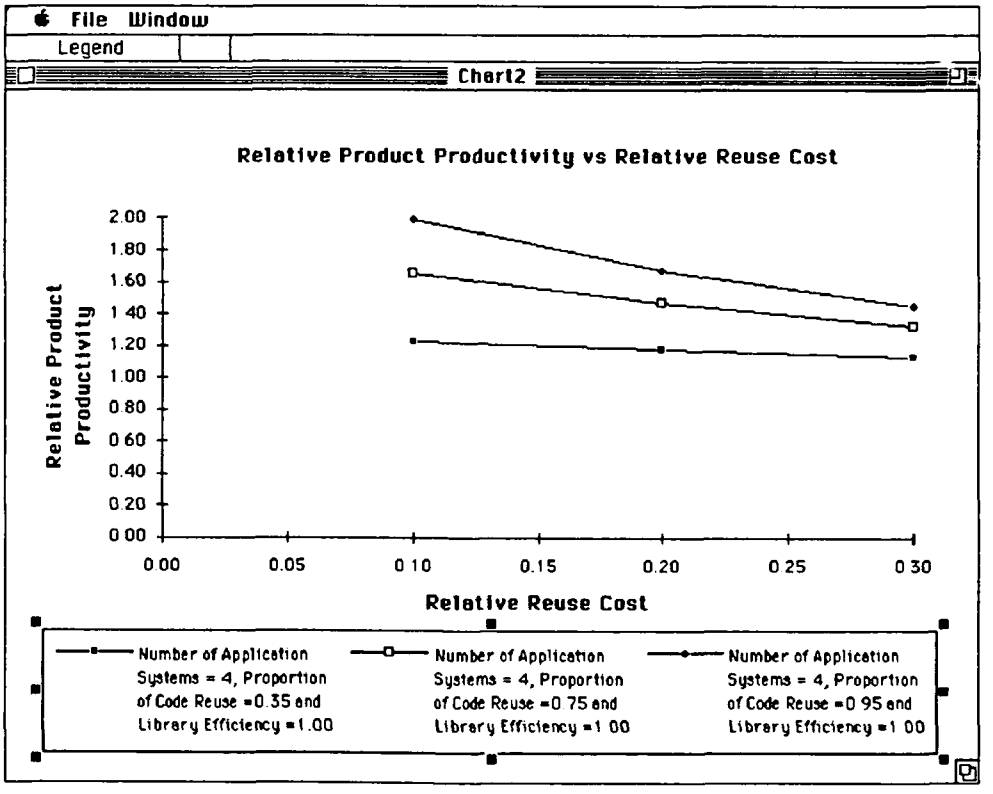


Figure 4-17. Mode 1a—Relative Product Productivity vs Relative Reuse Cost Graph Window

Table 4-3 shows the input data values that produced the graph in Figure 4-17.

Table 4-3. Input Data Values for Relative Product Productivity vs Relative Reuse Cost Graph Window

Number of Application Systems (N)	Proportion of Code Reuse (R)	Unit Cost of Reuse Program Investment (C_{DE})	Unit Cost of New Code (C_{VN})	Unit Cost of Reused Code (C_{VR})	Relative Library Capacity (K)
4	0.35	7.5	5	0.5	0.35
4	0.75	7.5	5	0.5	0.75
4	0.95	7.5	5	0.5	0.95
4	0.35	7.5	5	1.0	0.35
4	0.75	7.5	5	1.0	0.75
4	0.95	7.5	5	1.0	0.95
4	0.35	7.5	5	1.5	0.35
4	0.75	7.5	5	1.5	0.75
4	0.95	7.5	5	1.5	0.95

EXAMPLE: The data for each curve is selected based on the values you specify for the Proportion of Code Reuse (R), Number of Application Systems (N), and the Library Efficiency (E). Using the dialog boxes shown in Figures 4-15 and 4-16, the first curve will display a point for each row in the Model1aDB.xls worksheet (see Figures 4-5, 4-6, and 4-7) with R = 0.35, N = 4, and E = 1. Similarly, the second curve will display a point for each row in the Model1aDB.xls worksheet (see Figures 4-5, 4-6, and 4-7) with R = 0.75, N = 4, and E = 1. The data displayed in Table 4-3 shows a set of three points for each curve. The first point is represented by the rows with Unit Cost of Reused Code (CVR) = 0.5. The second point of each curve has CVR = 1. The third point of each curve has CVR = 1.5. In each case, you will notice that R = K. This forces the value for E to equal 1. Thus, we get the desired display. This graph displays the effect on Relative Product Productivity (P) of varying R as CVR increases, assuming that maximal reuse of code is occurring and other parameters are held constant. To generate the Relative Product Productivity vs Relative Reuse Cost Graph for R = 0.35, 0.75, and 0.95 with N = 4 and E = 1:

1. Scan your data to be sure that it does not contain extra rows that match your intended selection criteria but are not meant to be plotted (e.g., you might have a row with N = 4, CDE = 15, CVN = 10, CVR = 1, and E = 1, which is not comparable to the data shown above because the unit costs are not the same). If such data exists, eliminate it from selection by temporarily modifying its value for the selection criteria (e.g., you could set N = 10 to eliminate it from selection).

2. Select Relative Product Productivity vs Relative Reuse Cost from the Graphs menu to display the Graph2A Inputs Dialog Box (as shown in Figure 4-15).

3. Select Number of curves to plot = 3.

4. Select Proportion of Code Reuse for Curve 1 = 0.35.

5. Select Proportion of Code Reuse for Curve 2 = 0.75.

6. Select Proportion of Code Reuse for Curve 3 = 0.95.

7. Click the [OK] button in the Graph2a Inputs Dialog Box to display the Graph2b Inputs Dialog Box (as shown in Figure 4-16).

8. Select Number of Application Systems = 4.

9. Select Library Efficiency for all curves = 1.

10. Click the [OK] button in the Graph2B Inputs Dialog Box to display the graph for the selected data (as shown in Figure 4-17).

4.4.4.3 Product Productivity vs Number of Application Systems Graph

The Product Productivity vs Number of Application Systems graph format provides up to three graphs of product productivity, P_U ($P_U = 1{,}000/C_{US}$), versus the number of application systems, N. The three graphs differ with respect to the values of R, the proportion of code reuse, that you select.

NOTE: You should ensure that all of the points plotted use the same values for the unit costs of reuse program investment (C_{DE}), new code (C_{VN}), and reusing code (C_{VR}).

One dialog box appears for entering your data (shown in Figure 4-18).

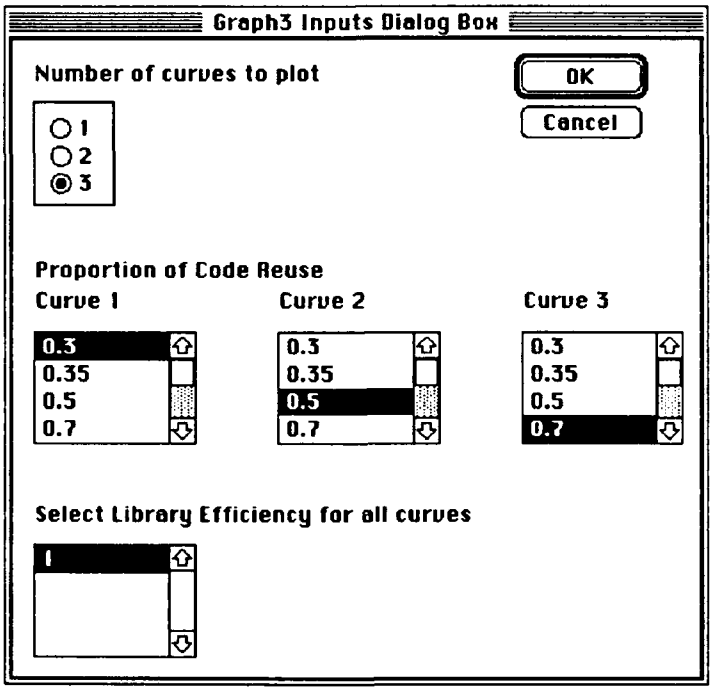


Figure 4-18. Mode 1a—Graph3 Inputs Dialog Box

The Graph3 Inputs Dialog Box requests values for the number of curves to plot, the proportion of code reuse for each curve, and the library efficiency to use in all plots.

- To specify a value for the number of curves to plot, select the appropriate option button.

- To specify the values for the proportion of code reuse for each curve, select a value from the list box corresponding to each desired curve.

- To specify a value for the library efficiency, select a value from the corresponding list box.
- To have the selected inputs accepted by the application, click the [OK] button and the graph build operation will continue.
- Clicking the [Cancel] button will terminate the graph build operation and return control to the Mode 1a window.

When you complete your entries, the graph window displays the resultant graph (see Figure 4-19). Note that the "cross-over" in the plots at a value of N, the number of application systems, is slightly less than 2. The cross-over occurs at a value of $N = N_0$, the break-even number of systems. For N less than N_0, higher values of R (the proportion of reuse) make the unit cost of an application system more expensive.

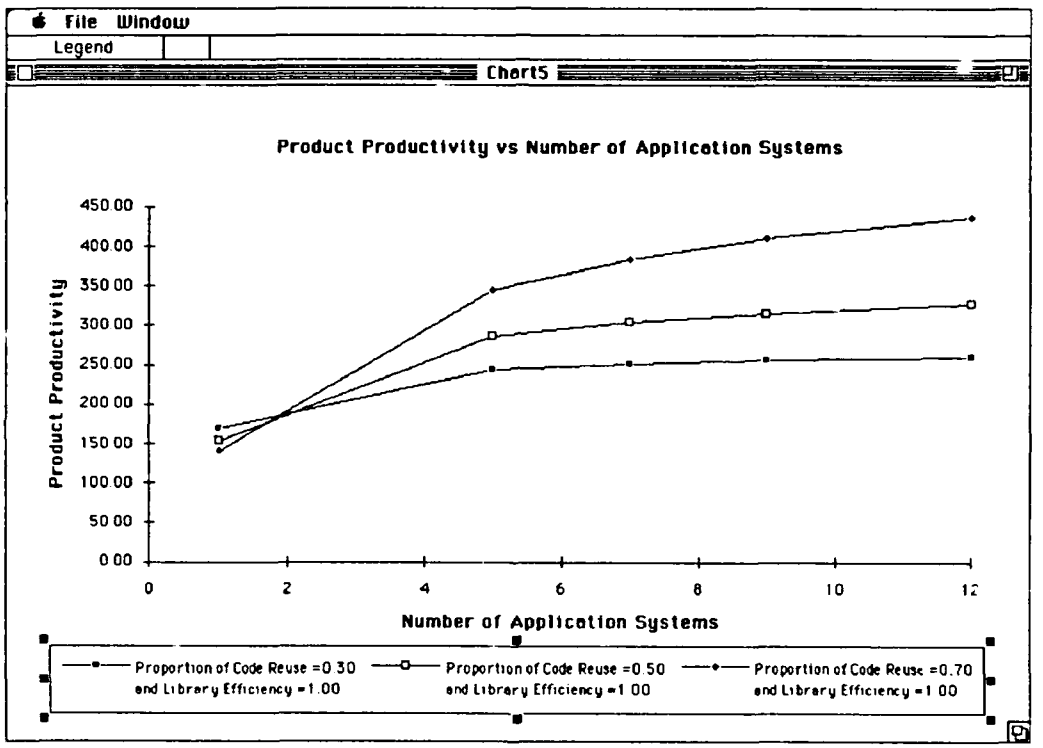


Figure 4-19. Mode 1a—Product Productivity vs Number of Application Systems Graph Window

Table 4-4 shows the input data values that produced the graph in Figure 4-19.

EXAMPLE: The data for each curve is selected based on the values you specify for the Proportion of Code Reuse (R) and the Library Efficiency (E). Using the dialog box shown in Figure 4-18, the first curve will display a point for each row in the Mode1aDB.xls worksheet (see Figures 4-5, 4-6, and 4-7) with R = 0.3 and E = 1. Similarly, the second curve will display a point for each row in the Mode1aDB.xls worksheet (see Figures 4-5, 4-6, and 4-7) with R = 0.5 and E = 1. The data displayed in Table 4-4 shows a set of five points for each curve. The first point is represented by the rows with Number of Application Systems (N) = 1. The second point of each curve has N = 2. The third point of each curve has N = 5. In each case, you will notice that R = K. This forces the value for E to equal 1. Thus, we get the desired display. This graph displays the effect on Product Productivity (PU) of varying R as N increases (assuming that maximal reuse of code is occurring and holding other parameters constant). To generate the Product Productivity vs Number of Application Systems Graph for R = 0.3, 0.5, and 0.7 with E = 1:

Table 4-4. Input Data Values for Product Productivity vs Number of Application Systems Graph Window

Number of Application Systems (N)	Proportion of Code Reuse (R)	Unit Cost of Reuse Program Investment (C_{DE})	Unit Cost of New Code (C_{VN})	Unit Cost of Reused Code (C_{VR})	Relative Library Capacity (K)
1	0.3	7.5	5	0.5	0.3
1	0.5	7.5	5	0.5	0.5
1	0.7	7.5	5	0.5	0.7
5	0.3	7.5	5	0.5	0.3
5	0.5	7.5	5	0.5	0.5
5	0.7	7.5	5	0.5	0.7
7	0.3	7.5	5	0.5	0.3
7	0.5	7.5	5	0.5	0.5
7	0.7	7.5	5	0.5	0.7
9	0.3	7.5	5	0.5	0.3
9	0.5	7.5	5	0.5	0.5
9	0.7	7.5	5	0.5	0.7
12	0.3	7.5	5	0.5	0.3
12	0.5	7.5	5	0.5	0.5
12	0.7	7.5	5	0.5	0.7

1. Scan your data to be sure that it does not contain extra rows that match your intended selection criteria but are not meant to be plotted (e.g., you might have a row with N = 1, R = 0.3, CDE = 15, CVN = 10, CVR = 1, and K = 0.3, which is not comparable to the data shown above because the unit costs are not the same). If such data exists, eliminate it from selection by temporarily modifying its value for the selection keys (e.g., you could set K = 0.4 to eliminate it from selection).

2. Select Product Productivity vs Number of Application Systems from the Graphs menu to display the Graph3 Inputs Dialog Box (as shown in Figure 4-18).

3. Select Number of curves to plot = 3.

4. Select Proportion of Code Reuse for Curve 1 = 0.3.

5. Select Proportion of Code Reuse for Curve 2 = 0.5.

6. Select Proportion of Code Reuse for Curve 3 = 0.7.

7. Select Library Efficiency for all curves = 1.

8. Click the [OK] button in the Graph3 Inputs Dialog Box to display the graph for the selected data (as shown in Figure 4-19).

4.4.4.4 Return on Investment vs Number of Application Systems Graph

The Return on Investment vs Number of Application Systems graph format provides up to three graphs of return on investment (ROI) versus the number of application systems, N. The three graphs differ with respect to the value of E, the library efficiency, that you use.

NOTE: You should ensure that all of the points plotted use the same values for the unit costs of reuse program investment (C_{DE}), new code (C_{VN}), and reusing code (C_{VR}).

One dialog box appears for entering your data (shown in Figure 4-20).

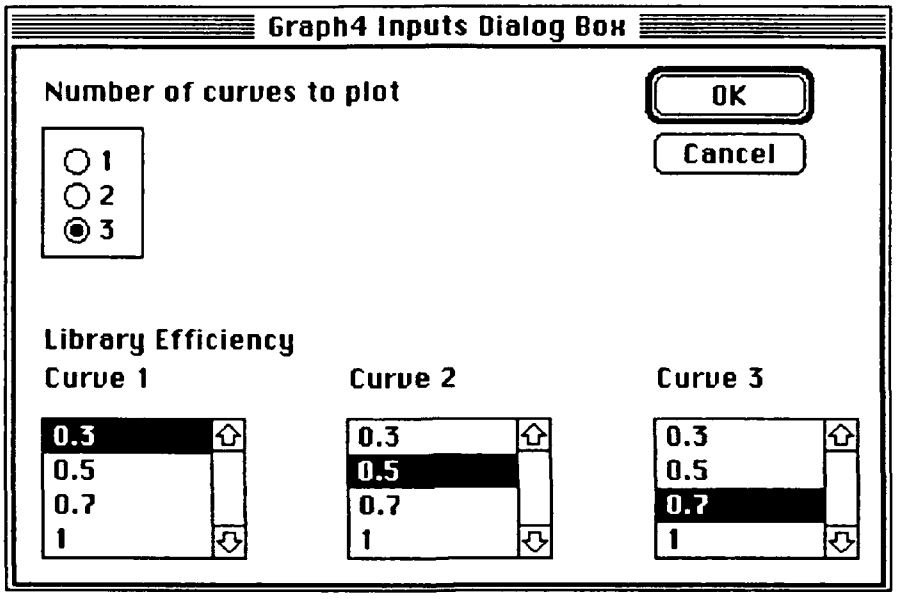


Figure 4-20. Mode 1a—Graph4 Inputs Dialog Box

The Graph4 Inputs Dialog Box requests values for the number of curves to plot and the library efficiency for each curve.

- To specify a value for the number of curves to plot, select the appropriate option button.
- To specify the values for the library efficiency for each curve, select a value from the list box corresponding to each desired curve.
- To have the selected inputs accepted by the application, click the [OK] button and the graph build operation will continue.
- Clicking the [Cancel] button will terminate the graph build operation and return control to the Mode 1a window.

When you complete your entries, the graph window displays the graph (see Figure 4-21). Note that the ROI is negative when N, the number of application systems, is less than N_0, the break-even number of systems.

Table 4-5 shows the input data values that produced the graph in Figure 4-21.

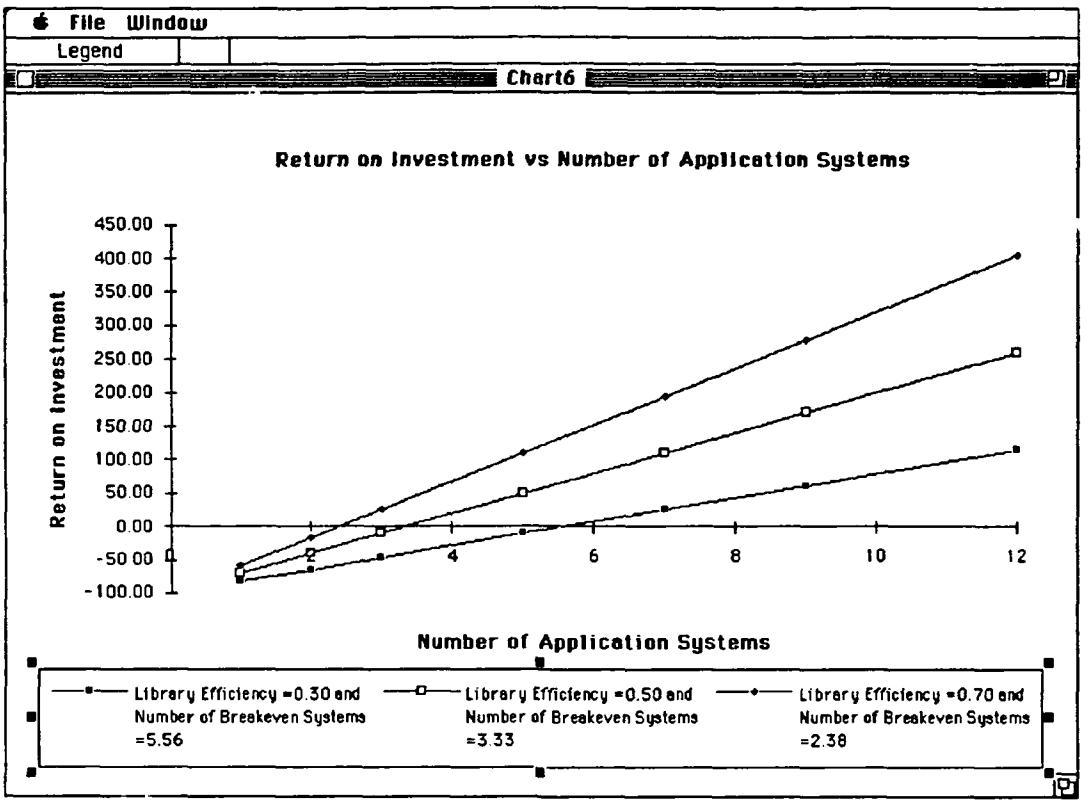


Figure 4-21. Mode 1a—Return on Investment vs Number of Application Systems Graph Window

Table 4-5. Input Data Values for Return on Investment vs Number of Application Systems Graph Window

Number of Application Systems (N)	Proportion of Code Reuse (R)	Unit Cost of Reuse Program Investment (C_{DE})	Unit Cost of New Code (C_{VN})	Unit Cost of Reused Code (C_{VR})	Relative Library Capacity (K)
1	0.3	7.5	5	0.5	1.0
1	0.5	7.5	5	0.5	1.0
1	0.7	7.5	5	0.5	1.0
5	0.3	7.5	5	0.5	1.0
5	0.5	7.5	5	0.5	1.0
5	0.7	7.5	5	0.5	1.0
7	0.3	7.5	5	0.5	1.0
7	0.5	7.5	5	0.5	1.0
7	0.7	7.5	5	0.5	1.0
9	0.3	7.5	5	0.5	1.0
9	0.5	7.5	5	0.5	1.0
9	0.7	7.5	5	0.5	1.0
12	0.3	7.5	5	0.5	1.0
12	0.5	7.5	5	0.5	1.0
12	0.7	7.5	5	0.5	1.0

EXAMPLE: The data for each curve is selected based on the values you specify for the Library Efficiency (E). Using the dialog box shown in Figure 4-20, the first curve will display a point for each row in the Model1aDB.xls worksheet (see Figures 4-5, 4-6, and 4-7) with E = 0.3. Similarly, the second curve will display a point for each row in the Model1aDB.xls worksheet (see Figures 4-5, 4-6, and 4-7) with E = 0.5. The data displayed in Table 4-5 shows a set of five points for each curve. The first point is represented by the rows with Number of Application Systems (N) = 1. The second point of each curve has N = 2. The third point of each curve has N = 5. In each case, you will notice that K = 1. This means that the library covers 100% of the functionality of the application system (ST = SS). This forces the value for E to numerically equal R (as E = R/K and K = 1). Therefore, we get the five points for each value of R and, hence, the desired display. This graph displays the effect on ROI of varying E as N increases (holding other parameters constant). To generate the Return on Investment vs Number of Application Systems Graph for E = 0.3, 0.5, and 0.7:

1. Scan your data to be sure that it does not contain extra rows that match your intended selection criteria but are not meant to be plotted (e.g., you might have a row with N = 1, R = 0.3, CDE = 15, CVN = 10, CVR = 1, and K = 1, which is not comparable to the data shown above because the unit costs are not the same). If such data exists, eliminate it from selection by temporarily modifying its value for the selection keys (e.g., you could set K = 0.4, thereby forcing E = 0.75 to eliminate it from selection). Because K is a computed value, you must modify the values for ST and SS to change the value of K. Similarly, E is a computed value and, as such, must be modified by changing the value of K or R.

2. Select Return on Investment vs Number of Application Systems from the Graphs menu to display the Graph4 Inputs Dialog Box (as shown in Figure 4-20).

3. Select Number of curves to plot = 3.

4. Select Library Efficiency for Curve 1 = 0.3.

5. Select Library Efficiency for Curve 2 = 0.5.

6. Select Library Efficiency for Curve 3 = 0.7.

7. Click the [OK] button in the Graph4 Inputs Dialog Box to display the graph for the selected data (as shown in Figure 4-21).

4.4.4.5 Labor Months vs Number of Application Systems Graph

The Labor Months vs Number of Application Systems graph provides a bar chart which shows Reuse Program Investment, Cost per System With All New Code, Application Engineering Cost per System, and Reuse Program Investment Cost per System for each of the N applications in the selected reuse scenario.

One dialog box appears for entering your data (shown in Figure 4-22).

The Graph5 Inputs Dialog Box requests a value for the family number of the reuse scenario to plot.

- To specify a value for the family number:
  - Select a value from the corresponding list box.

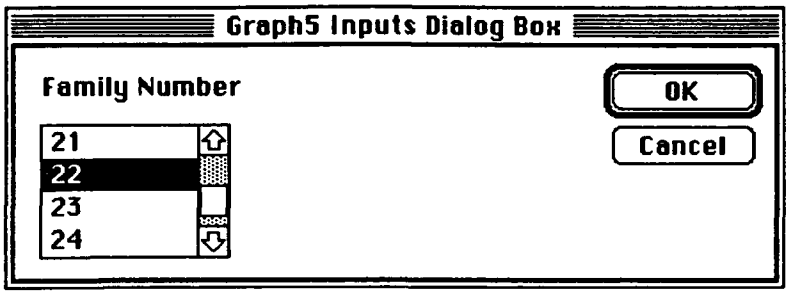


Figure 4-22. Mode 1a—Graph5 Inputs Dialog Box

- Click the [OK] button to transmit the selected value to the application and continue building the graph.

  NOTE: Pressing <RETURN> in response to a dialog box is the same as clicking the [OK] button.

- Clicking the [Cancel] button will terminate the graph build operation and return control to the Mode 1a window.

When you complete your entries, the graph window displays the graph (see Figure 4-23).

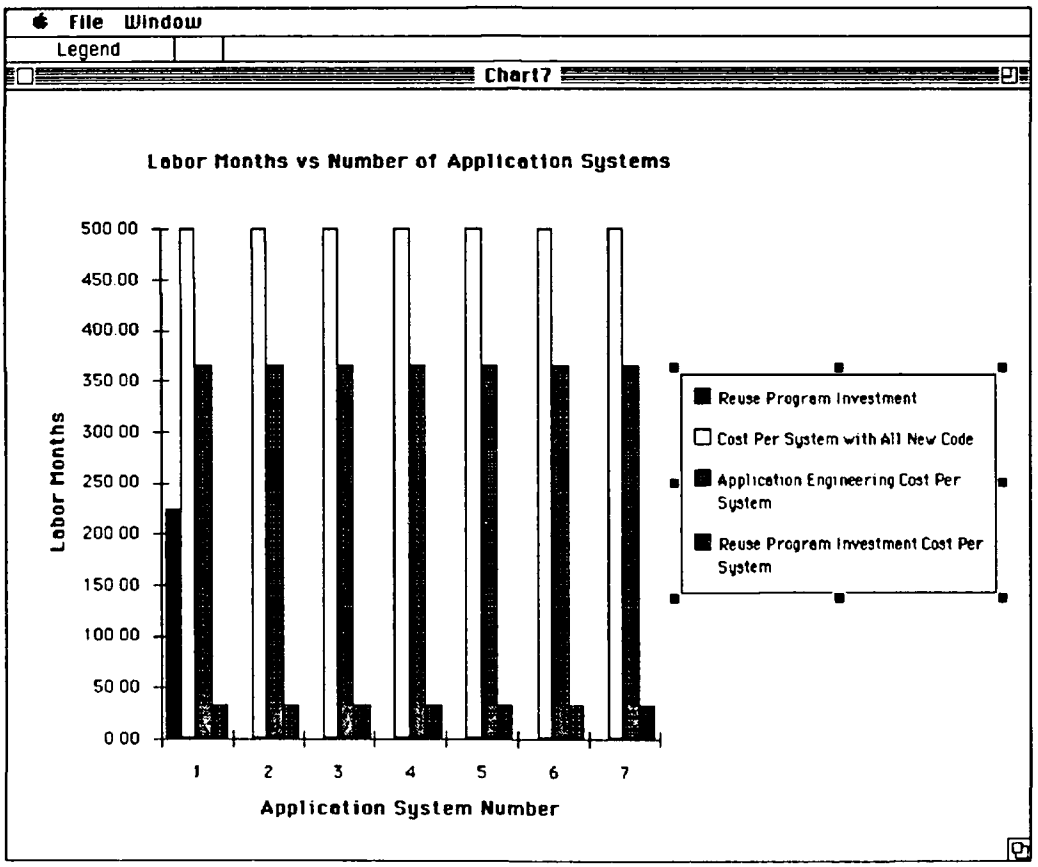


Figure 4-23. Mode 1a—Labor Months vs Number of Application Systems Graph Window

Table 4-6 shows the input data values that produced the graph in Figure 4-23.

Table 4-6. Input Data Values for Labor Months vs Number of Application Systems Graph Window

Number of Application Systems (N)	Proportion of Code Reuse (R)	Unit Cost of Reuse Program Investment (C_{DE})	Unit Cost of New Code (C_{VN})	Unit Cost of Reused Code (C_{VR})	Size of Reuse Library (ST)	Average Size of Application System (SS)	Relative Library Capacity (K)
7	0.30	7.5	5	0.5	30	100	0.30

EXAMPLE: The data for family 22 represents a case where there are seven application systems in the family and all of the reuse program investment is done up front. All of the application systems in the family have R = 0.3, CDE = 7.5, CVN = 5, CVR = 0.5, ST = 30, SS = 100, and K = 0.3 To generate the Labor Months vs Number of Application Systems Graph for Family Number = 1:

1. Select Labor Months vs Number of Application Systems from the Graphs menu to display the Graph1 Inputs Dialog Box (as shown in Figure 4-22).

2. Select Family Number = 22.

3. Click the [OK] button in the Graph5 Inputs Dialog Box to display the graph for the selected family (as shown in Figure 4-23).

4.4.5 The Window Menu

The Window menu provides the Arrange All option, which allows you to simultaneously display all open windows. This is useful for viewing multiple graphs at the same time. A sample display resulting from invoking the Arrange All menu selection is shown in Figure 4-4.

4.5 THE MODE 2 WINDOW

The Mode 2 window appears when you select Incremental Reuse Program Investment Without Cost of Money from the Modes menu of the Main window. It provides access to all other system functions for Mode 2 operation. The window consists of a custom menu bar and a Microsoft Excel worksheet (see Figures 4-24, 4-25, 4-26, 4-27, and 4-28). The menu bar contains the File, Family, Application, Graphs, and Window menus.

The worksheet contains the rows of data that either you entered or were computed from the values you entered. Each column of data corresponds to a variable described in the reuse economics model detailed in Cruickshank and Gaffney (1991) and summarized in Appendix A. Table 4-7 shows the mapping of column names to variable names.

Section 4.5.3 describes the use of the sample data set presented in Figure 4-24.

File Family Application Graphs Window

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Mode2DB.xls

	A	B	C	D	E	F	G	H
1	FamilyNo	I	N	CDE	CVN	CVR	CVNi	CVRi
2	Family Number	Application Number	Number of Application Systems	Base Unit Cost of Reuse Program Investment	Base Unit Cost of New Code	Base Unit Cost of Reused Code	Unit Cost of New Code for the ith Application System	Unit Cost of Reused Code for the ith Application System
4	1	1	5	7.50	5.00	0.50	5.00	0.50
5	1	2	5	7.50	5.00	0.50	5.00	0.50
6	1	3	5	7.50	5.00	0.50	5.00	0.50
7	1	4	5	7.50	5.00	0.50	5.00	0.50
8	1	5	5	7.50	5.00	0.50	5.00	0.50
9	2	1	5	7.50	5.00	0.50	5.00	0.50
10	2	2	5	7.50	5.00	0.50	5.00	0.50
11	2	3	5	7.50	5.00	0.50	5.00	0.50
12	2	4	5	7.50	5.00	0.50	5.00	0.50
13	2	5	5	7.50	5.00	0.50	5.00	0.50
14	3	1	5	7.50	5.00	0.50	5.00	0.50
15	3	2	5	7.50	5.00	0.50	5.00	0.50
16	3	3	5	7.50	5.00	0.50	5.00	0.50
17	3	4	5	7.50	5.00	0.50	5.00	0.50
18	3	5	5	7.50	5.00	0.50	5.00	0.50
19	4	1	5	7.50	5.00	0.50	5.00	0.50
20	4	2	5	7.50	5.00	0.50	5.00	0.50
21	4	3	5	7.50	5.00	0.50	5.00	0.50
22	4	4	5	7.50	5.00	0.50	5.00	0.50
23	4	5	5	7.50	5.00	0.50	5.00	0.50
24	5	1	5	7.50	5.00	0.50	5.00	0.50

Figure 4-24. Mode 2 Window (part 1)

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	I	J	K	L	M	N	O	P
1	STi	ST	SNi	SRi	SSi	Ri	Ki	CUSi
2	Amount of Reuse Library associated with ith Application System	Size of Reuse Library	Amount of New Code Developed for the ith Application System	Amount of Reused Code Incorporated in the ith Application System	Total Size of the ith Application System	Proportion of Code Reuse for the ith Application System	Relative Library Capacity for the ith Application System	Unit Cost of ith Application System
4	450.00	450.00	50.00	450.00	500.00	0.90	0.90	2.30
5	0.00	450.00	50.00	450.00	500.00	0.90	0.90	2.30
6	0.00	450.00	50.00	450.00	500.00	0.90	0.90	2.30
7	0.00	450.00	50.00	450.00	500.00	0.90	0.90	2.30
8	0.00	450.00	50.00	450.00	500.00	0.90	0.90	2.30
9	225.00	450.00	275.00	225.00	500.00	0.45	0.45	3.65
10	225.00	450.00	50.00	450.00	500.00	0.90	0.90	2.47
11	0.00	450.00	50.00	450.00	500.00	0.90	0.90	2.47
12	0.00	450.00	50.00	450.00	500.00	0.90	0.90	2.47
13	0.00	450.00	50.00	450.00	500.00	0.90	0.90	2.47
14	112.50	450.00	387.50	112.50	500.00	0.23	0.23	4.33
15	112.50	450.00	275.00	225.00	500.00	0.45	0.45	3.73
16	112.50	450.00	162.50	337.50	500.00	0.68	0.68	3.28
17	112.50	450.00	50.00	450.00	500.00	0.90	0.90	3.12
18	0.00	450.00	50.00	450.00	500.00	0.90	0.90	3.12
19	150.00	450.00	350.00	150.00	500.00	0.30	0.30	4.10
20	120.00	450.00	230.00	270.00	500.00	0.54	0.54	3.47
21	90.00	450.00	140.00	360.00	500.00	0.72	0.72	3.11
22	60.00	450.00	80.00	420.00	500.00	0.84	0.84	3.02
23	30.00	450.00	50.00	450.00	500.00	0.90	0.90	3.20
24	112.50	450.00	387.50	112.50	500.00	0.23	0.23	4.33

Figure 4-25. Mode 2 Window (part 2)

File Family Application Graphs Window

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Mode2DB.xls

	Q	R	S	T	U	V	W
1	CS	CAI	CDESumTerms1	CDESTi	CT	PU	P
2	Cost of Product	Application Engineering Cost Per System	Reuse Program Investment Cost Per System	Reuse Program Investment	Cost Per System with All New Code	Product Productivity	Relative Product Productivity
4	1150.00	475.00	675.00	3375.00	2500.00	434.78	2.17
5	1150.00	475.00	675.00	0.00	2500.00	434.78	2.17
6	1150.00	475.00	675.00	0.00	2500.00	434.78	2.17
7	1150.00	475.00	675.00	0.00	2500.00	434.78	2.17
8	1150.00	475.00	675.00	0.00	2500.00	434.78	2.17
9	1825.00	1487.50	337.50	1687.50	2500.00	273.97	1.37
10	1234.38	475.00	759.38	1687.50	2500.00	405.06	2.03
11	1234.38	475.00	759.38	0.00	2500.00	405.06	2.03
12	1234.38	475.00	759.38	0.00	2500.00	405.06	2.03
13	1234.38	475.00	759.38	0.00	2500.00	405.06	2.03
14	2162.50	1993.75	168.75	843.75	2500.00	231.21	1.16
15	1867.19	1487.50	379.69	843.75	2500.00	267.78	1.34
16	1642.19	981.25	660.94	843.75	2500.00	304.47	1.52
17	1557.81	475.00	1082.81	843.75	2500.00	320.96	1.60
18	1557.81	475.00	1082.81	0.00	2500.00	320.96	1.60
19	2050.00	1825.00	225.00	1125.00	2500.00	243.90	1.22
20	1735.00	1285.00	450.00	900.00	2500.00	288.18	1.44
21	1555.00	880.00	675.00	675.00	2500.00	321.54	1.61
22	1510.00	610.00	900.00	450.00	2500.00	331.13	1.66
23	1600.00	475.00	1125.00	225.00	2500.00	312.50	1.56
24	2162.50	1993.75	168.75	843.75	2500.00	231.21	1.16

Figure 4-26. Mode 2 Window (part 3)

File Family Application Graphs Window

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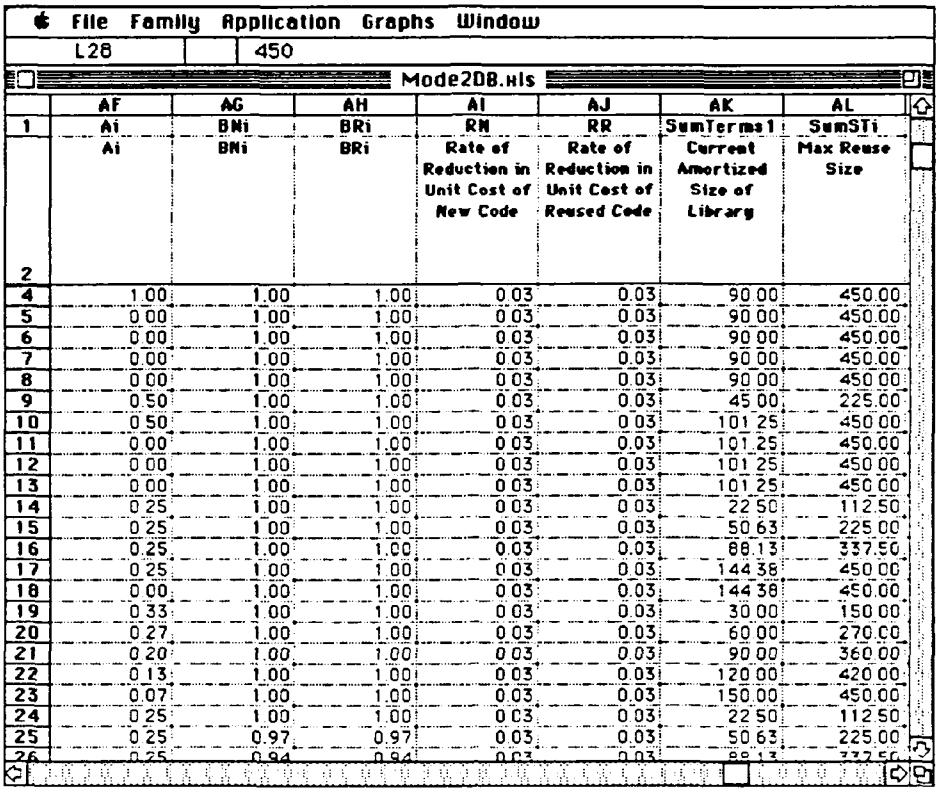
	X	Y	Z	AA	AB	AC	AD	AE
1	C	CYRR	SumCT	SumCDESTi	SumCS	ROI	Ei	ISP
2	Relative Product Cost	Relative Reuse Cost	Sum Cost Per System with All New Code	Sum Reuse Program Investment	Sum Cost of Product	Return on Investment	Library Efficiency	Incremental Spending Penalty
4	0.46	0.10	12500.00	3375.00	5750.00	200.00	1.00	0.00
5	0.46	0.10	12500.00	3375.00	5750.00	200.00	1.00	0.00
6	0.46	0.10	12500.00	3375.00	5750.00	200.00	1.00	0.00
7	0.46	0.10	12500.00	3375.00	5750.00	200.00	1.00	0.00
8	0.46	0.10	12500.00	3375.00	5750.00	200.00	1.00	0.00
9	0.73	0.10	12500.00	3375.00	6762.50	170.00	1.00	0.50
10	0.49	0.10	12500.00	3375.00	6762.50	170.00	1.00	0.50
11	0.49	0.10	12500.00	3375.00	6762.50	170.00	1.00	0.50
12	0.49	0.10	12500.00	3375.00	6762.50	170.00	1.00	0.50
13	0.49	0.10	12500.00	3375.00	6762.50	170.00	1.00	0.50
14	0.87	0.10	12500.00	3375.00	8787.50	110.00	1.00	1.50
15	0.75	0.10	12500.00	3375.00	8787.50	110.00	1.00	1.50
16	0.66	0.10	12500.00	3375.00	8787.50	110.00	1.00	1.50
17	0.62	0.10	12500.00	3375.00	8787.50	110.00	1.00	1.50
18	0.62	0.10	12500.00	3375.00	8787.50	110.00	1.00	1.50
19	0.82	0.10	12500.00	3375.00	8450.00	120.00	1.00	1.33
20	0.69	0.10	12500.00	3375.00	8450.00	120.00	1.00	1.33
21	0.62	0.10	12500.00	3375.00	8450.00	120.00	1.00	1.33
22	0.60	0.10	12500.00	3375.00	8450.00	120.00	1.00	1.33
23	0.64	0.10	12500.00	3375.00	8450.00	120.00	1.00	1.33
24	0.87	0.10	11772.16	3375.00	8568.92	94.32	1.00	1.50
25	0.75	0.10	11772.16	3375.00	8568.92	94.32	1.00	1.50

Figure 4-27. Mode 2 Window (part 4)



	AF	AG	AH	AI	AJ	AK	AL
1	Ai	BNi	BRi	RN	RR	SumTerms1	SumSTi
2	Ai	BNi	BRi	Rate of Reduction in Unit Cost of New Code	Rate of Reduction in Unit Cost of Reused Code	Current Amortized Size of Library	Max Reuse Size
4	1.00	1.00	1.00	0.03	0.03	90.00	450.00
5	0.00	1.00	1.00	0.03	0.03	90.00	450.00
6	0.00	1.00	1.00	0.03	0.03	90.00	450.00
7	0.00	1.00	1.00	0.03	0.03	90.00	450.00
8	0.00	1.00	1.00	0.03	0.03	90.00	450.00
9	0.50	1.00	1.00	0.03	0.03	45.00	225.00
10	0.50	1.00	1.00	0.03	0.03	101.25	450.00
11	0.00	1.00	1.00	0.03	0.03	101.25	450.00
12	0.00	1.00	1.00	0.03	0.03	101.25	450.00
13	0.00	1.00	1.00	0.03	0.03	101.25	450.00
14	0.25	1.00	1.00	0.03	0.03	22.50	112.50
15	0.25	1.00	1.00	0.03	0.03	50.63	225.00
16	0.25	1.00	1.00	0.03	0.03	88.13	337.50
17	0.25	1.00	1.00	0.03	0.03	144.38	450.00
18	0.00	1.00	1.00	0.03	0.03	144.38	450.00
19	0.33	1.00	1.00	0.03	0.03	30.00	150.00
20	0.27	1.00	1.00	0.03	0.03	60.00	270.00
21	0.20	1.00	1.00	0.03	0.03	90.00	360.00
22	0.13	1.00	1.00	0.03	0.03	120.00	420.00
23	0.07	1.00	1.00	0.03	0.03	150.00	450.00
24	0.25	1.00	1.00	0.03	0.03	22.50	112.50
25	0.25	0.97	0.97	0.03	0.03	50.63	225.00
26	0.25	0.94	0.94	0.03	0.03	88.13	337.50

Figure 4-28. Mode 2 Window (part 5)

Table 4-7. Mapping of Worksheet Column Names to Reuse Economic Model Variable Names

Worksheet Column Label	Worksheet Column Name	Variable Name*	Constraints
A	Family Number	FamilyNo	$0 <$ FamilyNo
B	Application Number	I	$0 <$ I
C	Number of Application Systems	N	$0 <$ N
D	Base Unit Cost of Reuse Program Investment	C_{DE}	$0 < C_{DE}$
E	Base Unit Cost of New Code	C_{VN}	$0 < C_{VN}$
F	Base Unit Cost of Reused Code	C_{VR}	$0 < C_{VR}$
G	Unit Cost of New Code for the i^{th} Application System	C_{VNi}	$0 < C_{VN_i}$

Table 4-7, continued

Worksheet Column Label	Worksheet Column Name	Variable Name*	Constraints
H	Unit Cost of Reused Code for the i^{th} Application System	C_{VRi}	$0 < C_{VR_i}$
I	Amount of Reuse Library Associated With the i^{th} Application System	ST_i	$0 \leq ST_i$
J	Size of Reuse Library	ST	$ST = \sum_{i=1}^{N} ST_i$
K	Amount of New Code Developed for the i^{th} Application System	SN_i	$0 \leq SN_i$
L	Amount of Reused Code Incorporated in the i^{th} Application System	SR_i	$0 \leq SR_i \leq SumSTi$
M	Total Size of the i^{th} Application System	SS_i	$SS_i = SN_i + SR_i$
N	Proportion of Code Reuse for the i^{th} Application System	R_i	$R_i = SR_i/SS_i$
O	Relative Library Capacity for the i^{th} Application System	K_i	$K_i = \sum_{m=1}^{i} ST_m/SS_i$
P	Unit Cost of i^{th} Application System	C_{USi}	$C_{US_i} = [(C_{DE}/SS_i) \cdot SumTerms1] + C_{VN_i} - [(C_{VN_i} - C_{VR_i}) \cdot R_i]$
Q	Cost of Product	C_{Si}	$CS_i = C_{US_i} \cdot SS_i$
R	Application Engineering Cost per System	C_{Ai}	$C_{A_i} = (C_{VN_i} \cdot SS_i) - [(C_{VN_i} - C_{VR_i}) \cdot SR_i]$

Table 4-7, continued

Worksheet Column Label	Worksheet Column Name	Variable Name*	Constraints
S	Reuse Program Investment Cost per System	$C_{DE}SumTerms1$	$C_{DE}SumTerms1 = C_{DE} \cdot SumTerms1$
T	Reuse Program Investment	$C_{DE}ST_i$	$C_{DE}ST_i = C_{DE} \cdot ST_i$
U	Cost per System With All New Code	CT_i	$CT_i = C_{VN_i} \cdot SS_i$
V	Product Productivity	PU	$PU = 1,000/C_{US_i}$
W	Relative Product Productivity	P	$P = C_{VN_i}/C_{US_i}$
X	Relative Product Cost	C	$C = 1/P$
Y	Relative Reuse Cost	C_{VRR}	$C_{VRR} = C_{VR_i}/C_{VN_i}$
Z	Sum Cost of System With All New Code	$SumCT_i$	$SumCT_i = \sum_{i=1}^{N} CT_i$
AA	Sum Reuse Program Investment	$SumC_{DE}ST_i$	$SumC_{DE}ST_i = \sum_{i=1}^{N} C_{DE}ST_i$
AB	Sum Cost of Product	$SumCS_i$	$SumCS_i = \sum_{i=1}^{N} CS_i$
AC	Return on Investment	ROI	$ROI = [(SumCT_i - SumCS_i)/SumC_{DE}ST_i] \cdot 100$
AD	Library Efficiency	E_i	$E_i = R_i/K_i$
AE	Incremental Spending Penalty	ISP	$ISP = \sum_{i=1}^{N} (i-1) \cdot a_i$
AF	Ai	a_i	$a_i = ST_i/ST$
AG	BNi	BN_i	$BN_i = (1-RN)^{(i-1)}$
AH	BRi	BR_i	$BR_i = (1-RR)^{(i-1)}$
AI	Rate of Reduction in Unit Cost of New Code	RN	$0 \leq RN < 1$

Table 4-7, continued

Worksheet Column Label	Worksheet Column Name	Variable Name*	Constraints
AJ	Rate of Reduction in Unit Cost of Reused Code	RR	$0 \leq RR < 1$
AK	Current Amortized Size of Library	SumTerms1	$SumTerms1 = \sum_{m=1}^{i}(ST_m/(N-(m-1)))$
AL	Max Reuse Size	$SumST_i$	$SumST_i = \sum_{m=1}^{i} ST_m$

* Appendix A and Cruickshank and Gaffney (1991) use subscripts on some of these variables such as C_{DE} instead of CDE and C_{US} instead of CUS.

4.5.1 The File Menu

The File menu provides the following options:

- Print Preview
  - To print the worksheet, select Print Preview from the File menu. The standard Microsoft Excel Print Preview window then appears.

  Note: Attempting to print when there is no printer connected may result in a macro error. Should this happen, click the [Halt] button to return to normal operation.

- Save
  - To save changes made to the worksheet, select Save from the File menu. The tool saves the data and returns you to the Mode 2 window. Saving a worksheet overwrites the previous data with the current data. The tool maintains only one version of the worksheet and makes it accessible through the application.
  - To retain old data indefinitely, you should make a copy of the file Mode2DB.xls under a new name. Do this outside of the Reuse Economics Spreadsheet Model tool.
  - To restore old data, rename a saved file to Mode2DB.xls. You should be able to print a saved worksheet from Microsoft Excel. Saving old data under different file names is a way to preserve historical data associated with a particular graph or set of graphs.

- Close
  - To exit the Mode 2 window, select Close from the File menu. A dialog box appears to warn you if you have any unsaved changes.
  - Click the [Yes] or [No] button, as appropriate, to continue the Close process. When the Close process completes, the Main window appears.

4.5.2 Dialog Box Description

The Family and Application menu operations use a common dialog box interface. The interface for Modify operations consists of a sequence of two dialog boxes. The interface for Add and Delete operations consists of a single dialog box that is identical to the second dialog box displayed for a Modify operation.

The first dialog box contains check boxes for each of the modifiable fields. It allows you to specify which fields you wish to modify, thus providing protection against inadvertent data modification. You must select the check boxes for those fields that you wish to modify. Clicking the [OK] button causes the next dialog box in the sequence to be displayed. Clicking the [Cancel] button terminates the current operation and returns control to the Mode 2 window.

The second dialog box contains list boxes, number edit boxes, and option buttons. It allows you to enter and display data corresponding to a selected family or application. The fields of the dialog box are enabled or disabled in accordance with the type of operation to be performed. For example, when performing a family level operation, the Application Number list box is disabled. The list boxes are used for selecting family numbers and application numbers. The enabled number edit boxes are used for entering data for the selected family or application. The disabled number edit boxes are used to display constraints or current data values for your convenience. The option buttons are used to select the desired form of unit cost scaling. For example, select Set Default on the CVN Scale Factors option button group to display or enter the RN value. Clicking the [Refresh] button updates the screen to display the dialog box with the current values for the selected family or application shown in the number edit boxes. Clicking the [Accept] button carries out the current operation and returns control to the dialog box. Clicking the [Cancel] button terminates the current operation and returns control to the Mode 2 window.

The fields that are modifiable at the family level include those that are modifiable at the application level in addition to:

- ***CDE.*** This field corresponds to the Base Unit Cost of Reuse Program Investment. All applications within a family have the same value for CDE. Due to an implementation constraint that requires a nonzero value for CDE, it is not possible to exactly model the situation where there is no Reuse Program Investment (i.e., you are reusing library components that have been supplied to you at no cost). However, you can approximately model that situation by supplying a small value (e.g., 0.001) for CDE. This may cause the Return on Investment field to display a value too large for the column width. Such a situation is indicated by the presence of *###* instead of a numeric value in the worksheet cell.

- ***CVN.*** This field corresponds to the Base Unit Cost of New Code. All applications within a family have the same value for CVN. Each application may have a different CVN_i (Unit Cost of New Code for the i^{th} Application System), which is determined by adjusting the CVN Scale Factor (BN_i or RN) to obtain the desired CVN_i.

- ***CVR.*** This field corresponds to the Base Unit Cost of Reused Code. All applications within a family have the same value for CVR. Each application may have a different CVR_i (Unit Cost of Reused Code for the i^{th} Application System), which is determined by adjusting the CVR Scale Factor (BR_i or RR) to obtain the desired CVR_i.

The fields that are modifiable at the application level are:

- ***ST_i***. This field corresponds to the Amount of Reuse Library Associated with the i^{th} Application System.
- ***SN_i***. This field corresponds to the Amount of New Code Associated with the i^{th} Application System.
- ***SR_i***. This field corresponds to the Amount of Reused Code Associated with the i^{th} Application System.
- ***CVN Scale Factor.*** This field corresponds to either BN_i or RN. When the RN option button is on, the Value number edit box corresponds to RN. RN can be modified only at the family level. When the BN_i option button is on, the number edit box corresponds to BN_i.

  NOTE: The CVN Scale Factor is used to compute CVN_i by the formula $CVN_i = BN_i \cdot CVN$. The default scaling formula used to compute BN_i is $BN_i = (1 - RN)^{(i-1)}$.

- ***CVR Scale Factor.*** This field corresponds to either BR_i or RR. When the RR option button is on, the Value number edit box corresponds to RR. RR can be modified only at the family level. When the BR_i option button is on, the Value number edit box corresponds to BR_i.

  NOTE: The CVR Scale Factor is used to compute CVR_i by the formula $CVR_i = BR_i \cdot CVR$. The default scaling formula used to compute BR_i is $BR_i = (1 - RR)^{(i-1)}$.

4.5.3 The Family Menu

The Family menu consists of those operations that can be performed at the family level. Any parameter values supplied to a family level operation are assigned to all application systems in the family. This allows you to perform gross editing functions, such as assignment of unit costs or allocation of reuse program investment, when such assignments are constant across the family. To perform detailed editing functions, you should use the operations available under the Application menu.

The Family menu provides the following options:

- Add Family
  - To add a family:
    - Select Add Family from the Family menu. The Add Family Dialog Box then appears as shown in Figure 4-29.
    - Enter values in the fields provided, and click the [Accept] button. The new rows will be added to the end of the existing worksheet data. All of the rows will be identified by the same Family Number, and each of the N rows in the family (where N is the Number of Application Systems) will have the values specified for the input fields.
  - To view an existing family, select the desired Family Number from the Family Number list box, and click the [Refresh] button. The data for the selected family will be shown in the corresponding dialog box fields.

- Clicking the [Cancel] button will terminate the Add Family operation and return control to the Mode 2 window.

NOTE: Pressing <RETURN> is the same as clicking the [Refresh] button.

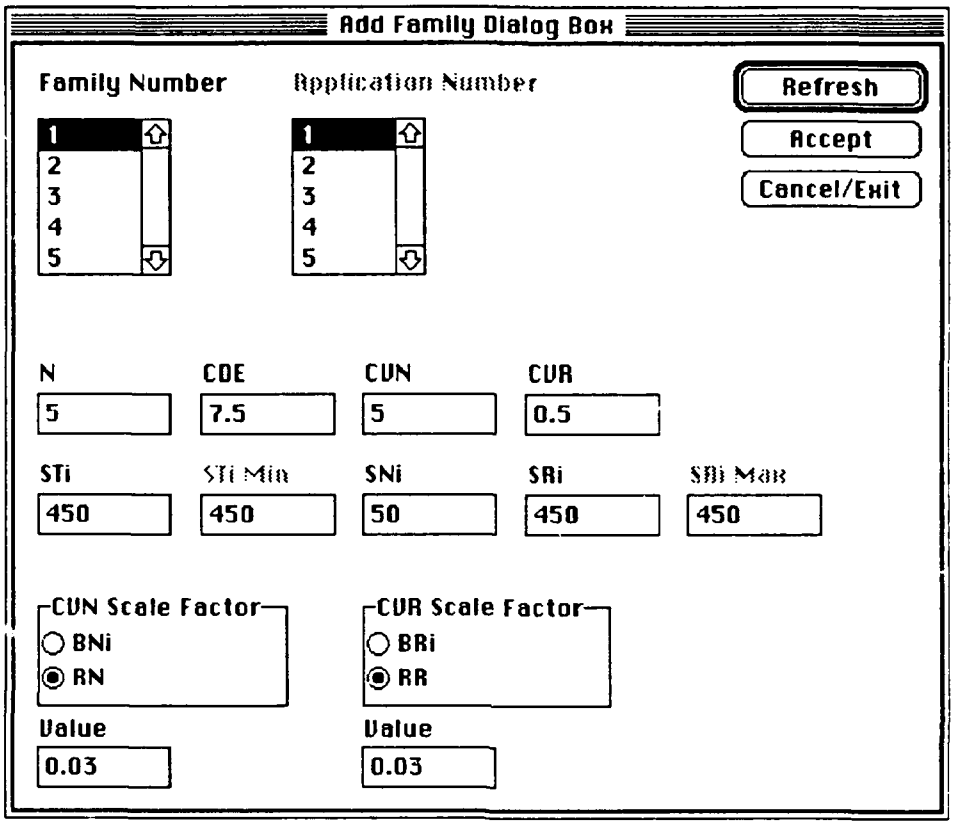


Figure 4-29. Mode 2—Add Family Dialog Box

EXAMPLE: To create a family with parameter values N = 5, CDE = 7.5, CVN = 5, CVR = 0.5, STi = 50, SNi = 50, SRi = 50, RN = 0.03, and RR = 0.03:

1. Select Add Family from the Family menu to display the Add Family Dialog Box.
2. If there is an existing family with similar parameter values, select the existing family number and click the [Refresh] button to display the parameter values for that family. Then modify the parameters to the appropriate values for the new family. If the dialog box contains the data as displayed in Figure 4-29, then you need only change the values for STi and SRi from 450 to 50 because all of the other values are correct.
3. If there is no existing family with similar parameter values, just modify the displayed parameter values that need to be changed for the new family.
4. Click the [Accept] button to create the new family.
5. Click the [Cancel] button to terminate the Add Family operation.

EXAMPLE: To create a family with parameter values N = 5, CDE = 7.5, CVN = 5, CVR = 0.5, ST1 = 150, ST2 = 120, ST3 = 90, ST4 = 60, ST5 = 30, SN1 = 350, SN2 = 230, SN3 = 140, SN4 = 80, SN5 = 50, SR1 = 150, SR2 = 270, SR3 = 360, SR4 = 420, SR5 = 450, RN = 0.03, and RR = 0.03:

1. Select Add Family from the Family menu to display the Add Family Dialog Box.

2. Modify the displayed parameter values to N = 5, CDE = 7.5, CVN = 5, CVR = 0.5, STi = 150, SNi = 350, SRi = 150, RN = 0.03, and RR = 0.03. There is a constraint that the value for SRi cannot be greater than the sum of the STi values up to and including the i^{th} application system. Therefore, SR1 must be less than or equal to ST1. Similarly, SR2 must be less than or equal to ST1 + ST2. etc.

3. Click the [Accept] button to create the new family.

4. Click the [Cancel] button to terminate the Add Family operation.

5. Perform the Modify Application System operation to adjust the values for STi, SNi, and SRi for each of the application systems in the newly created family.

- Modify Family
  - To modify a family:
    - Select Modify Family from the Family menu. The Modify Family Dialog Box1 then appears as shown in Figure 4-30.
    - Select the boxes corresponding to those values that are to be modified.
    - Click the [OK] button to proceed to Modify Family Dialog Box2 as shown in Figure 4-31.
    - Click the [Cancel] button to terminate the Modify Family operation.
    - Select the corresponding Family Number by clicking the mouse button to highlight the number in the Family Number list box of the Modify Family Dialog Box2. Then enter those values that you wish to modify.
  - Clicking the [Accept] button will modify the rows of the selected family and return control to the Modify Family Dialog Box2.
  - Clicking the [Refresh] button will update the dialog box to display the current values for the selected family.
  - Clicking the [Cancel] button will terminate the Modify Family operation and return control to the Mode 2 window.

EXAMPLE: To modify a family to set parameters STi = 500, SNi = 600, and SRi = 450:

1. Select Modify Family from the Family menu to display the Modify Family Dialog Box1.

2. Select the check boxes for STi, SNi, and SRi (as shown in Figure 4-30). Make sure the check boxes for nonmodifiable fields are deselected.

3. Click the [OK] button to proceed to the Modify Family Dialog Box2 (as shown in Figure 4-31).

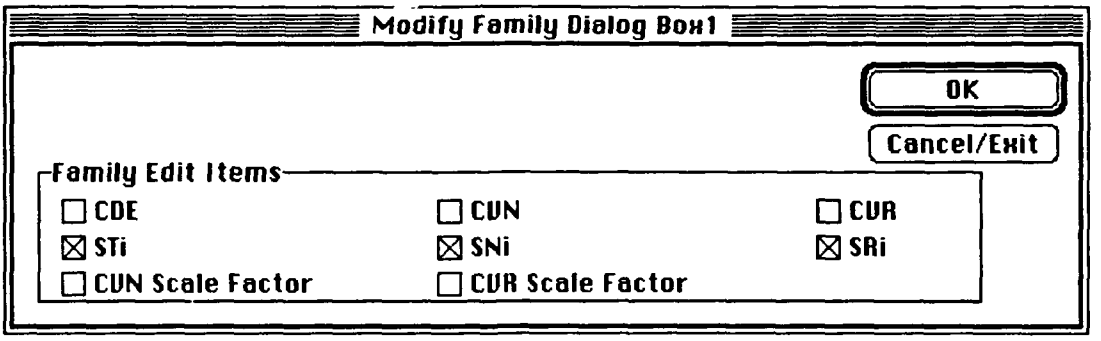


Figure 4-30. Mode 2—Modify Family Dialog Box1

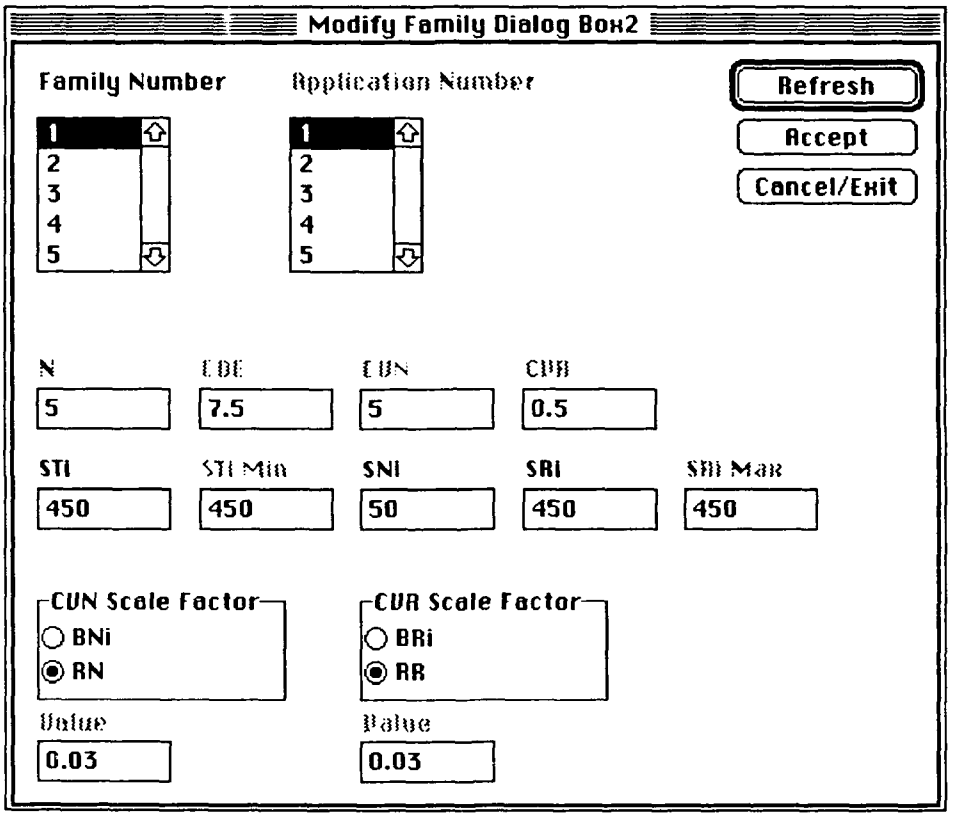


Figure 4-31. Mode 2—Modify Family Dialog Box2

4. Select the Family Number for the family that you wish to modify.

5. Click the [Refresh] button to display the parameter values for the selected family.

6. Set the parameter values STi = 500, SNi = 600, and SRi = 450 in the appropriate fields.

7. Click the [Accept] button to modify the selected family.

8. Click the [Cancel] button to terminate the Modify Family operation.

- Delete Family
  - To delete a family:
    - — Select Delete Family from the Family menu. The Delete Family Dialog Box then appears as shown in Figure 4-32.
    - — Select the corresponding Family Number by clicking the mouse button to highlight the number in the Family Number list box.
  - Clicking the [Accept] button will cause the Delete Confirmation Dialog Box to be displayed (see Figure 4-12).
    - — Click the [OK] button if you wish to proceed with the delete operation. The rows of the selected family will be deleted and the remaining worksheet data will be renumbered to reflect the number of different families represented in the worksheet.
    - — Click the [Cancel] button if you wish to abort the delete operation.
  - Clicking the [Refresh] button will update the dialog box with the current values for the selected family.
  - Clicking the [Cancel] button will terminate the Delete Family operation and return control to the Mode 2 window.

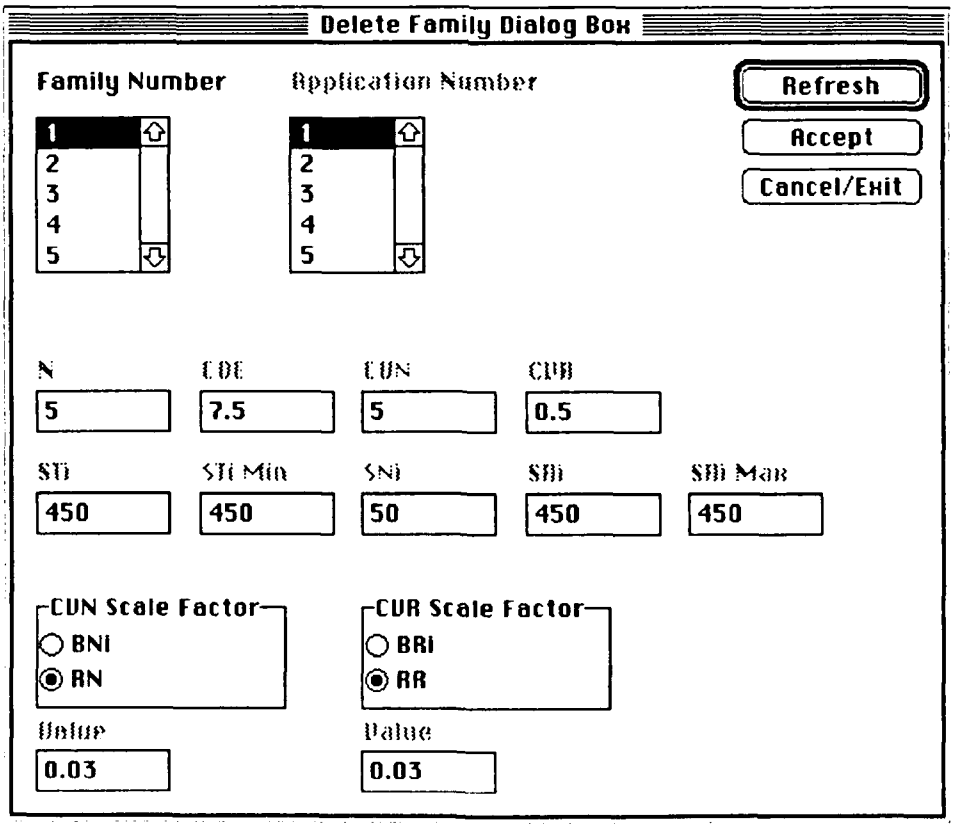


Figure 4-32. Mode 2—Delete Family Dialog Box

EXAMPLE: To delete a family:

1. Select Delete Family from the Family menu to display the Delete Family Dialog Box (as shown in Figure 4-32).
2. Select the Family Number for the family that you wish to delete.
3. Click the [Refresh] button to display the parameter values for the selected family (just to make sure that you have selected the correct family).
4. Click the [Accept] button to proceed to the Delete Confirmation Dialog Box (as shown in Figure 4-12).
5. Click the [OK] button in the Delete Confirmation Dialog Box to delete the selected family and display the Delete Family Dialog Box.
6. Click the [Cancel] button in the Delete Family Dialog Box to terminate the Delete Family operation.

4.5.4 THE APPLICATION MENU

The Application menu provides the following options:

- Add Application System
  - To add N rows to a family:
    - — Select Add Application System from the Application menu. The Add Application System Dialog Box then appears as shown in Figure 4-33.
    - — Enter N in the Number of Application Systems field along with the desired values in the fields provided and click the [Accept] button. The new rows will be added to the selected family after the selected application.
  - Clicking the [Refresh] button will update the screen to display the values for the selected application in the selected family.
  - Clicking the [Cancel] button will terminate the Add operation and return control to the Mode 2 window.

EXAMPLE: To add two application systems to a family:

1. Select Add Application System from the Application menu to display the Add Application System Dialog Box.
2. Select the Family Number of the family to be modified.
3. Select the Application Number of the application that you wish to use as a model for the new application systems.
4. Click the [Refresh] button to display the parameters for the selected application system.
5. Set the parameter value N = 2.

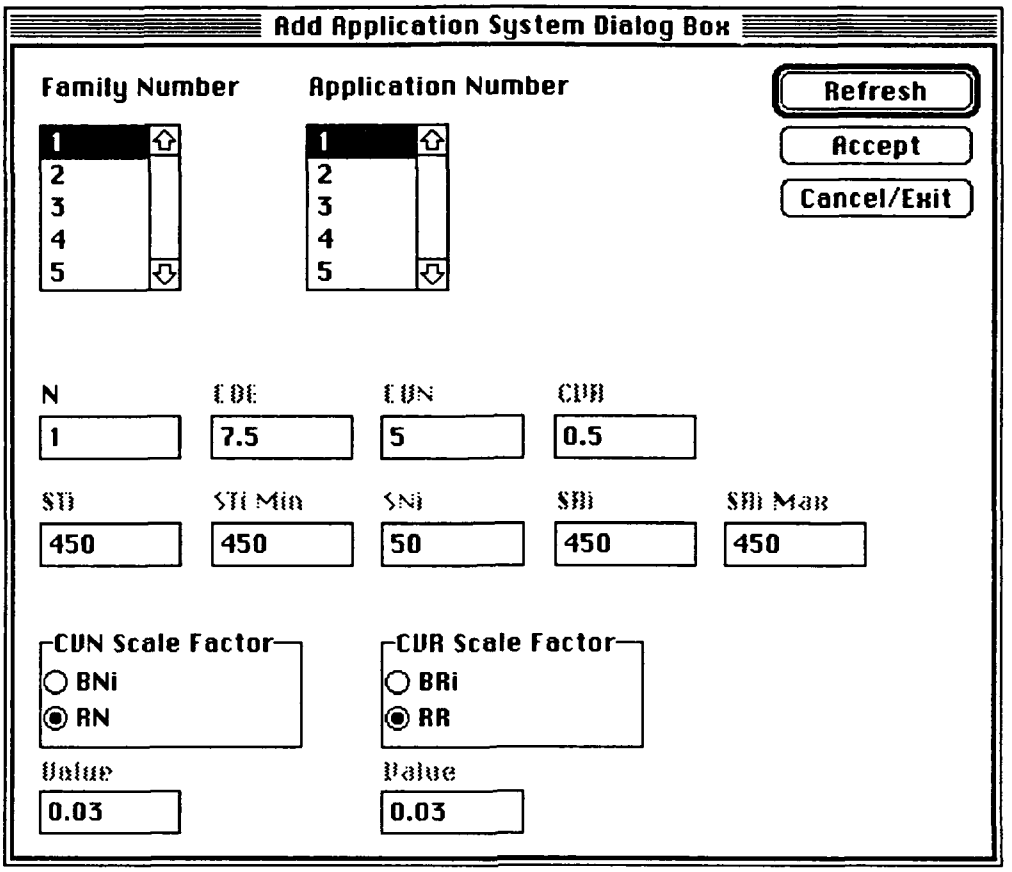


Figure 4-33. Mode 2—Add Application System Dialog Box

6. Click the [Accept] button to create two new application systems. If the selected application number = i, the added application systems will be duplicates of application system i and will be assigned application numbers i + 1 and i + 2, respectively. The applications in the family will be renumbered to account for the added application systems.

7. Click the [Cancel] button to terminate the Add Application System operation.

8. Perform Modify Application System to adjust the parameter values for each of the newly created application systems.

- Modify Application System
  - To modify an application in a family:
    -- Select Modify Application System from the Application menu. The Modify Application System Dialog Box1 then appears as shown in Figure 4-34.
    -- Select the boxes corresponding to those values that are to be modified.
    -- Click the [OK] button to proceed to Modify Application System Dialog Box2 as shown in Figure 4-35.
    -- Click the [Cancel] button to terminate the Modify Application System operation.

— Select the corresponding family number and application number by clicking the mouse button to highlight the numbers in the Family Number and Application Number list boxes respectively. Then enter those values that you wish to modify.

- Clicking the [Accept] button will modify the selected application and return control to the Modify Application System Dialog Box2.
- Clicking the [Refresh] button will update the screen to display the current values for the selected application.
- Clicking the [Cancel] button will terminate the Modify Application System operation and return control to the Mode 2 window.

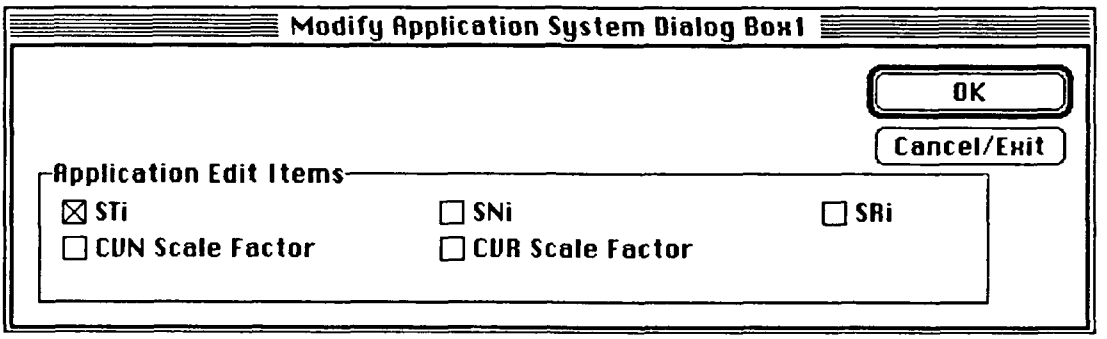


Figure 4-34. Mode 2—Modify Application System Dialog Box1

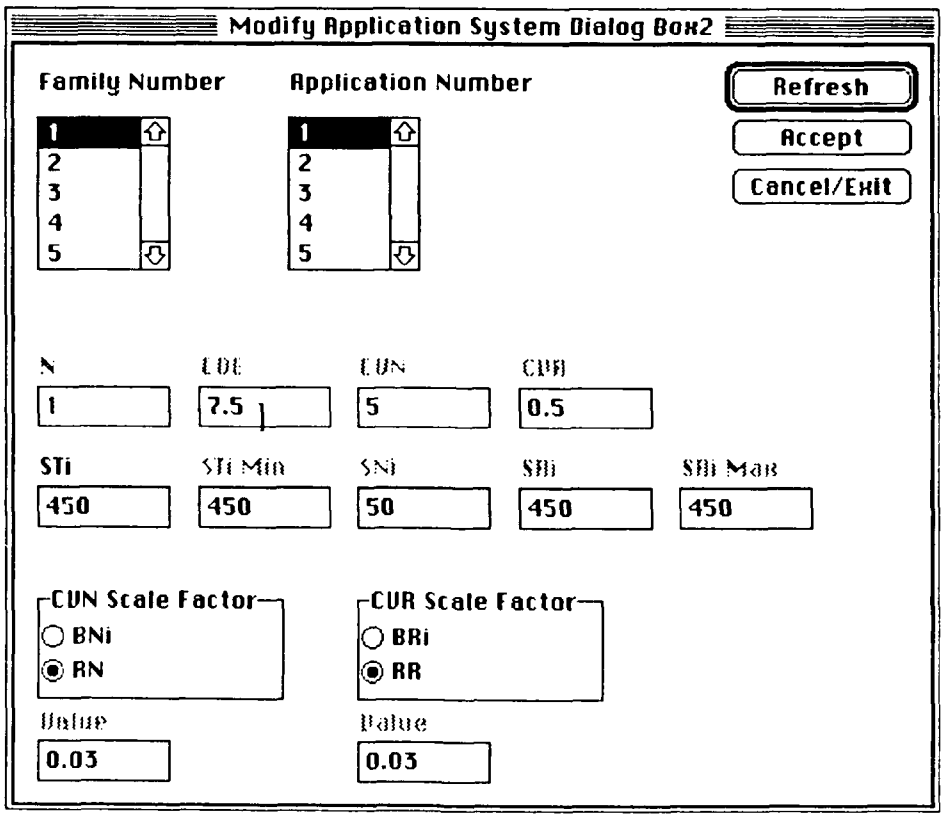


Figure 4-35. Mode 2—Modify Application System Dialog Box2

EXAMPLE: To modify the application systems in a family so that the parameter values are N = 5, CDE = 7.5, CVN = 5, CVR = 0.5, ST1 = 150, ST2 = 120, ST3 = 90, ST4 = 60, ST5 = 30, SN1 = 350, SN2 = 230, SN3 = 140, SN4 = 80, SN5 = 50, SR1 = 150, SR2 = 270, SR3 = 360, SR4 = 420, SR5 = 450, RN = 0.03, and RR = 0.03:

1. Select Modify Family from the Family menu to display the Modify Family Dialog Box1.
2. Select all of the check boxes.
3. Click the [OK] button to proceed to the Modify Family Dialog Box2.
4. Select the Family Number for the family that you wish to modify.
5. Click the [Refresh] button to display the parameter values for the selected family.
6. Set the parameter values CDE = 7.5, CVN = 5, CVR = 0.5, STi = 150, SNi = 350, SRi = 150, RN = 0.03, RR = 0.03.
7. Click the [Accept] button to modify the selected family.
8. Click the [Cancel] button to terminate Modify Family operation.
9. Select Modify Application System from the Application menu to display the Modify Application System Dialog Box1 (as shown in Figure 4-34).
10. Select the check boxes for STi, SNi, and SRi on the Modify Application System Dialog Box1.
11. Click the [OK] button to proceed to the Modify Application System Dialog Box2 (as shown in Figure 4-35).
12. Select the Family Number of the family to be modified.
13. Select Application Number = 1.
14. Click the [Refresh] button to display the parameters for the selected application system.
15. Set the parameter values STi = 150, SNi = 350, and SRi = 150.
16. Click the [Accept] button to modify the application system.
17. Select Application Number = 2.
18. Click the [Refresh] button to display the parameters for the selected application system.
19. Set the parameter values STi = 120, SNi = 230, and SRi = 270.
20. Click the [Accept] button to modify the application system.
21. Select Application Number = 3.
22. Click the [Refresh] button to display the parameters for the selected application system.
23. Set the parameter values STi = 90, SNi = 140, and SRi = 360.
24. Click the [Accept] button to modify the application system.

25. Select Application Number = 4.
26. Click the [Refresh] button to display the parameters for the selected application system.
27. Set the parameter values STi = 60, SNi = 80, and SRi = 420.
28. Click the [Accept] button to modify the application system.
29. Select Application Number = 5.
30. Click the [Refresh] button to display the parameters for the selected application system.
31. Set the parameter values STi = 30, SNi = 50, and SRi = 450.
32. Click the [Accept] button to modify the application system.
33. Click the [Cancel] button to terminate the Add Family operation.

- Delete Application System
  - To delete applications from a family:
    - — Select Delete from the Data menu. The Delete Application System Dialog Box then appears as shown in Figure 4-36.
    - — Select the corresponding family number and application number from the Family Number and Application Number list boxes, respectively. Enter the number of applications to delete in the number edit box labeled Number of Application Systems.

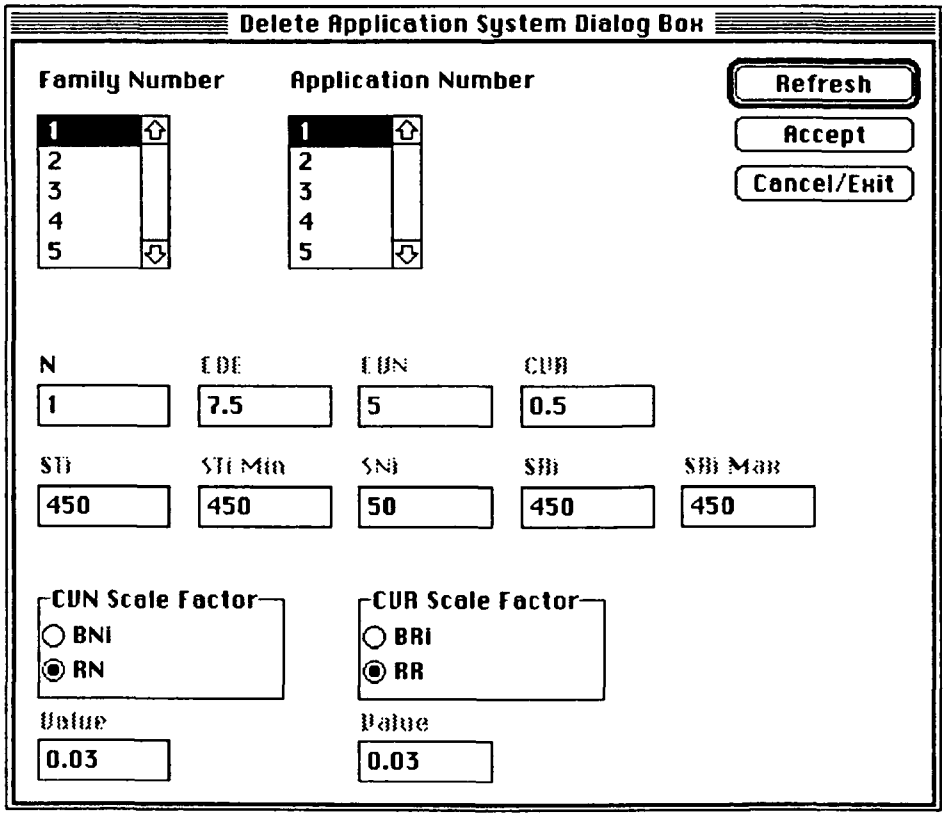


Figure 4-36. Mode 2—Delete Application System Dialog Box

- Clicking the [Accept] button will cause the Delete Confirmation Dialog Box to be displayed (see Figure 4-12).
  - — Click the [OK] button if you wish to proceed with the delete operation. The selected rows will be deleted from the selected family, and the remaining worksheet data will be renumbered to reflect the number of applications in the family.
  - — Click the [Cancel] button if you wish to abort the delete operation.
- Clicking the [Refresh] button updates the screen to display the current values for the selected application.
- Clicking the [Cancel] button will terminate the Delete Application System operation and return control to the Mode 2 window.

EXAMPLE: To delete Application Number = 2 from Family Number = 1:

1. Select Delete Application System from the Application menu to display the Delete Application System Dialog Box (as shown in Figure 4-36).
2. Select Family Number = 1.
3. Select Application Number = 2.
4. Click the [Refresh] button to display the parameter values for the selected application system (just to make sure that you have selected the correct application).
5. Click the [Accept] button to proceed to the Delete Confirmation Dialog Box (as shown in Figure 4-12).
6. Click the [OK] button in the Delete Confirmation Dialog Box to delete the selected application and to display the Delete Application System Dialog Box.
7. Click the [Cancel] button in the Delete Application System Dialog Box to terminate the Delete Application System operation.

4.5.5 The Graphs Menu

The Graphs menu generates the built-in graph for Mode 2 calculations. A dialog box appears when you select a graph from the Graphs menu. The input dialog box allows you to specify the reuse scenario family number to be used in the graph. To produce a graph from the worksheet data, select the desired graph from the Graphs menu. There is one built-in graph that you can produce in Mode 2: Labor Months vs Number of Application Systems.

4.5.5.1 Labor Months vs Number of Application Systems Graph

The Labor Months vs Number of Application Systems graph provides a bar chart measuring Reuse Program Investment, Cost per System With All New Code, Application Engineering Cost per System, and Reuse Program Investment Cost per System for each of the N applications in the selected reuse scenario.

When entering your data, a dialog box appears (shown in Figure 4-37).

The Graph1 Inputs Dialog Box requests a value for the family number of the reuse scenario to plot.

- To specify a value for the family number:
  - Select a value from the corresponding list box.
  - Click the [OK] button to transmit the selected value to the application and continue building the graph.

  NOTE: Pressing <RETURN> in response to a dialog box is the same as clicking the [OK] button.

- Clicking the [Cancel] button will terminate the graph build operation and return control to the Mode 2 window.

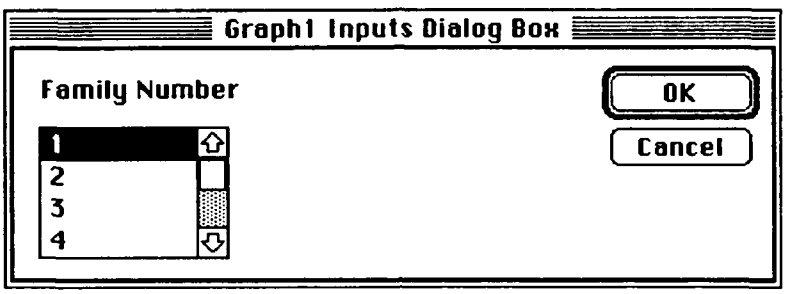


Figure 4-37. Mode 2—Graph1 Inputs Dialog Box

When you complete your entries, the graph window displays the resultant graph (see Figure 4-38).

Table 4-8 shows the input data values that produced this graph.

EXAMPLE: The data for family 1 represents a case where there are five application systems in the family and all of the reuse program investment is done during development of the first application system in the family. All of the subsequent application systems reuse the library components that were developed for that first system. To generate the Labor Months vs Number of Application Systems Graph for Family Number = 1:

Table 4-8. Input Data Values for Labor Months vs Number of Application Systems Graph Window

Application Number (i)	Number of Application Systems (N)	Base Unit Cost of Reuse Program Investment (C_{DE})	Base Unit Cost of New Code (C_{VN})	Base Unit Cost of Reused Code (C_{VR})	Amount of Reuse Library Associated With i^{th} Application System (ST_i)	Amount of New Code Developed for the i^{th} Application System (SN_i)	Amount of Reused Code Incorporated in the i^{th} Application System (SR_i)
1	5	7.5	5	0.5	450	50	450
2	5	7.5	5	0.5	0	50	450
3	5	7.5	5	0.5	0	50	450
4	5	7.5	5	0.5	0	50	450
5	5	7.5	5	0.5	0	50	450

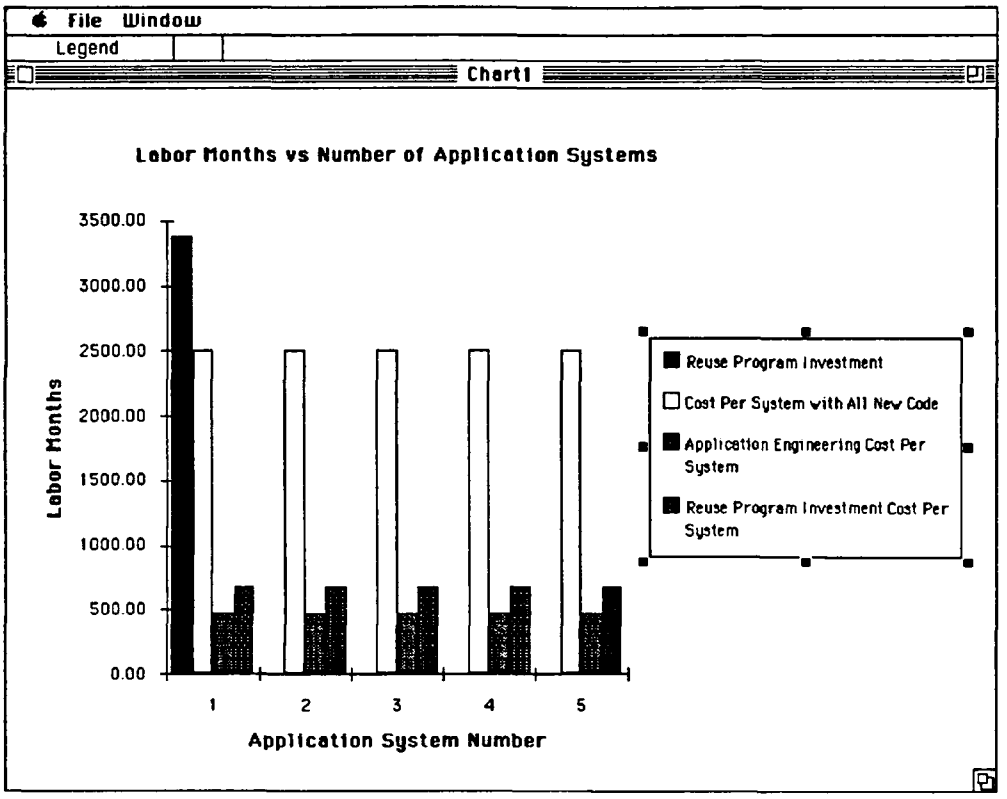


Figure 4-38. Mode 2—Labor Months vs Number of Application Systems Graph Window

1. Select Labor Months vs Number of Application Systems from the Graphs menu to display the Graph1 Inputs Dialog Box (as shown in Figure 4-37).
2. Select Family Number = 1.
3. Click the [OK] button in the Graph1 Inputs Dialog Box to display the graph for the selected family (as shown in Figure 4-38).

4.5.6 The Window Menu

The Window menu provides the following options:

- ***Arrange All.*** To simultaneously display all open windows, select Arrange All from the Window menu. This is useful for viewing multiple graphs at the same time.
- ***Calculate Now.*** To update the values displayed on the worksheet, select Calculate Now from the Window menu. This is useful for deferring time consuming updates until they are requested by the user.

4.6 THE MODE 3 WINDOW

The Mode 3 window appears when you select Incremental Reuse Program Investment With Cost of Money from the Modes menu of the Main window. It provides access to all other system functions for Mode 3 operation. The window consists of a custom menu bar and a Microsoft Excel worksheet (see Figures 4-39, 4-40, 4-41, 4-42, 4-43, and 4-44). The menu bar contains the File, Family, Application, Graphs, and Window menus.

File Family Application Graphs Window

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Mode3DB.xls

	A	B	C	D	E	F	G	H
1	FamilyNo	I	N	CDE	CVN	CVR	CVNi	CVRi
2	Family Number	Application Number	Number of Application Systems	Base Unit Cost of Reuse Program Investment	Base Unit Cost of New Code	Base Unit Cost of Reused Code	Unit Cost of New Code for the ith Application System	Unit Cost of Reused Code for the ith Application System
4	1	1	5	7.50	5.00	0.50	5.00	0.50
5	1	2	5	7.50	5.00	0.50	5.00	0.50
6	1	3	5	7.50	5.00	0.50	5.00	0.50
7	1	4	5	7.50	5.00	0.50	5.00	0.50
8	1	5	5	7.50	5.00	0.50	5.00	0.50
9	2	1	5	7.50	5.00	0.50	5.00	0.50
10	2	2	5	7.50	5.00	0.50	5.00	0.50
11	2	3	5	7.50	5.00	0.50	5.00	0.50
12	2	4	5	7.50	5.00	0.50	5.00	0.50
13	2	5	5	7.50	5.00	0.50	5.00	0.50
14	3	1	5	7.50	5.00	0.50	5.00	0.50
15	3	2	5	7.50	5.00	0.50	5.00	0.50
16	3	3	5	7.50	5.00	0.50	5.00	0.50
17	3	4	5	7.50	5.00	0.50	5.00	0.50
18	3	5	5	7.50	5.00	0.50	5.00	0.50
19	4	1	5	7.50	5.00	0.50	5.00	0.50
20	4	2	5	7.50	5.00	0.50	5.00	0.50
21	4	3	5	7.50	5.00	0.50	5.00	0.50
22	4	4	5	7.50	5.00	0.50	5.00	0.50
23	4	5	5	7.50	5.00	0.50	5.00	0.50
24	5	1	5	7.50	5.00	0.50	5.00	0.50

Figure 4-39. Mode 3 Window (part 1)

File Family Application Graphs Window

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Mode3DB.xls

	I	J	K	L	M	N	O	P
1	Rate	Years	STi	ST	SNi	SRi	SSi	RI
2	Interest Rate	Number of Years	Amount of Reuse Library associated with ith Application System	Size of Reuse Library	Amount of New Code Developed for the ith Application System	Amount of Reused Code Incorporated in the ith Application System	Total Size of the ith Application System	Proportion of Code Reuse for the ith Application System
4	8.00	4.00	450.00	450.00	50.00	450.00	500.00	0.90
5	8.00	4.00	0.00	450.00	50.00	450.00	500.00	0.90
6	8.00	4.00	0.00	450.00	50.00	450.00	500.00	0.90
7	8.00	4.00	0.00	450.00	50.00	450.00	500.00	0.90
8	8.00	4.00	0.00	450.00	50.00	450.00	500.00	0.90
9	8.00	4.00	225.00	450.00	275.00	225.00	500.00	0.45
10	8.00	4.00	225.00	450.00	50.00	450.00	500.00	0.90
11	8.00	4.00	0.00	450.00	50.00	450.00	500.00	0.90
12	8.00	4.00	0.00	450.00	50.00	450.00	500.00	0.90
13	8.00	4.00	0.00	450.00	50.00	450.00	500.00	0.90
14	8.00	4.00	112.50	450.00	387.50	112.50	500.00	0.23
15	8.00	4.00	112.50	450.00	275.00	225.00	500.00	0.45
16	8.00	4.00	112.50	450.00	162.50	337.50	500.00	0.68
17	8.00	4.00	112.50	450.00	50.00	450.00	500.00	0.90
18	8.00	4.00	0.00	450.00	50.00	450.00	500.00	0.90
19	8.00	4.00	150.00	450.00	350.00	150.00	500.00	0.30
20	8.00	4.00	120.00	450.00	230.00	270.00	500.00	0.54
21	8.00	4.00	90.00	450.00	140.00	360.00	500.00	0.72
22	8.00	4.00	60.00	450.00	80.00	420.00	500.00	0.84
23	8.00	4.00	30.00	450.00	50.00	450.00	500.00	0.90
24	8.00	4.00	112.50	450.00	387.50	112.50	500.00	0.23

Figure 4-40. Mode 3 Window (part 2)

File Family Application Graphs Window

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Mode30B.xls

	Q	R	S	T	U	Y	W
1	Ki	CUSi	CS	CAi	CDESumTerms1	CDESTi	CT
2	Relative Library Capacity for the ith Application System	Unit Cost of ith Application System	Cost of Product	Application Engineering Cost Per System	Reuse Program Investment Cost Per System	Reuse Program Investment	Cost Per System with All New Code
4	0.90	2.30	1150.00	475.00	675.00	3375.00	2500.00
5	0.90	2.30	1150.00	475.00	675.00	0.00	2500.00
6	0.90	2.30	1150.00	475.00	675.00	0.00	2500.00
7	0.90	2.30	1150.00	475.00	675.00	0.00	2500.00
8	0.90	2.30	1150.00	475.00	675.00	0.00	2500.00
9	0.45	3.65	1825.00	1487.50	337.50	1687.50	2500.00
10	0.90	2.47	1234.38	475.00	759.38	1687.50	2500.00
11	0.90	2.47	1234.38	475.00	759.38	0.00	2500.00
12	0.90	2.47	1234.38	475.00	759.38	0.00	2500.00
13	0.90	2.47	1234.38	475.00	759.38	0.00	2500.00
14	0.23	4.33	2162.50	1993.75	168.75	843.75	2500.00
15	0.45	3.73	1867.19	1487.50	379.69	843.75	2500.00
16	0.68	3.28	1642.19	981.25	660.94	843.75	2500.00
17	0.90	3.12	1557.81	475.00	1082.81	843.75	2500.00
18	0.90	3.12	1557.81	475.00	1082.81	0.00	2500.00
19	0.30	4.10	2050.00	1825.00	225.00	1125.00	2500.00
20	0.54	3.47	1735.00	1285.00	450.00	900.00	2500.00
21	0.72	3.11	1555.00	880.00	675.00	675.00	2500.00
22	0.84	3.02	1510.00	610.00	900.00	450.00	2500.00
23	0.90	3.20	1600.00	475.00	1125.00	225.00	2500.00
24	0.23	4.33	2162.50	1993.75	168.75	843.75	2500.00

Figure 4-41. Mode 3 Window (part 3)

File Family Application Graphs Window

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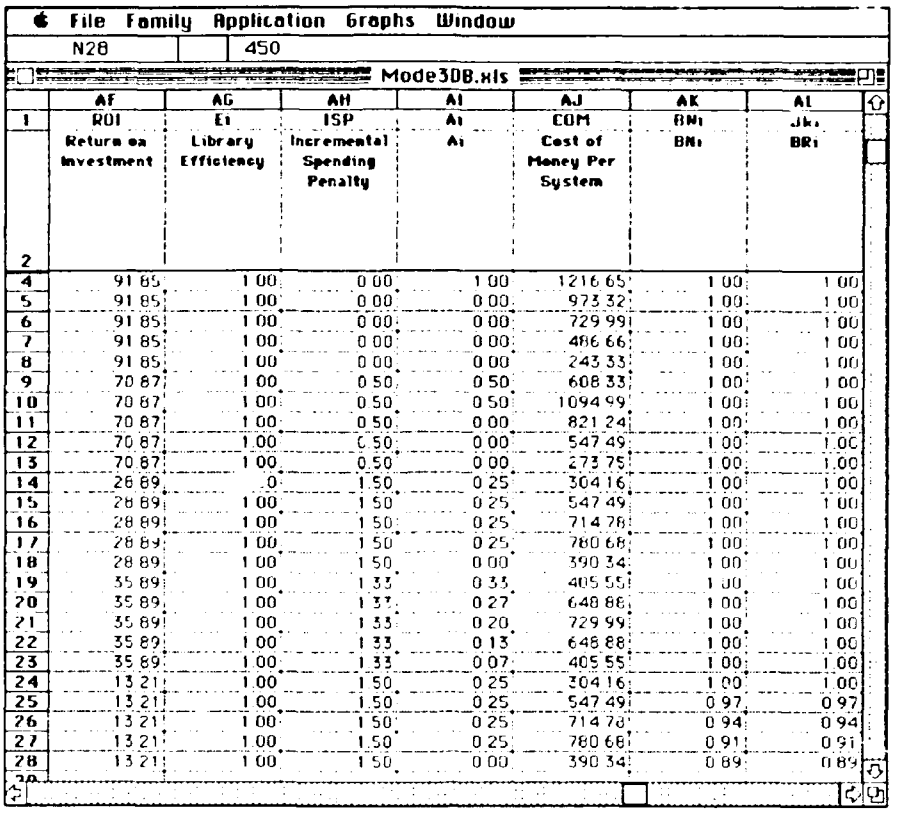
Mode30B.xls

	X	Y	Z	AA	AB	AC	AD	AE
1	PU	P	C	CYRR	SumCT	SumCDESTi	SumCS	SumCOM
2	Product Productivity	Relative Product Productivity	Relative Product Cost	Relative Reuse Cost	Sum Cost of System with All New Code	Sum Reuse Program Investment	Sum Cost of Product	Sum Cost of Money
4	434.78	2.17	0.46	0.10	12500.00	3375.00	5750.00	3649.95
5	434.78	2.17	0.46	0.10	12500.00	3375.00	5750.00	3649.95
6	434.78	2.17	0.46	0.10	12500.00	3375.00	5750.00	3649.95
7	434.78	2.17	0.46	0.10	12500.00	3375.00	5750.00	3649.95
8	434.78	2.17	0.46	0.10	12500.00	3375.00	5750.00	3649.95
9	273.97	1.37	0.73	0.10	12500.00	3375.00	6762.50	3345.79
10	405.06	2.03	0.49	0.10	12500.00	3375.00	6762.50	3345.79
11	405.06	2.03	0.49	0.10	12500.00	3375.00	6762.50	3345.79
12	405.06	2.03	0.49	0.10	12500.00	3375.00	6762.50	3345.79
13	405.06	2.03	0.49	0.10	12500.00	3375.00	6762.50	3345.79
14	231.21	1.16	0.87	0.10	12500.00	3375.00	8787.50	2737.46
15	267.78	1.34	0.75	0.10	12500.00	3375.00	8787.50	2737.46
16	304.47	1.52	0.66	0.10	12500.00	3375.00	8787.50	2737.46
17	320.96	1.60	0.62	0.10	12500.00	3375.00	8787.50	2737.46
18	320.96	1.60	0.62	0.10	12500.00	3375.00	8787.50	2737.46
19	243.90	1.22	0.82	0.10	12500.00	3375.00	8450.00	2638.65
20	288.18	1.44	0.69	0.10	12500.00	3375.00	8450.00	2638.65
21	321.54	1.61	0.62	0.10	12500.00	3375.00	8450.00	2638.65
22	331.13	1.66	0.60	0.10	12500.00	3375.00	8450.00	2638.65
23	312.50	1.56	0.64	0.10	12500.00	3375.00	8450.00	2638.65
24	231.21	1.16	0.87	0.10	11772.16	3375.00	8588.92	2737.46
25	274.34	1.33	0.75	0.10	11772.16	3375.00	8588.92	2737.46

Figure 4-42. Mode 3 Window (part 4)



File Family Application Graphs Window

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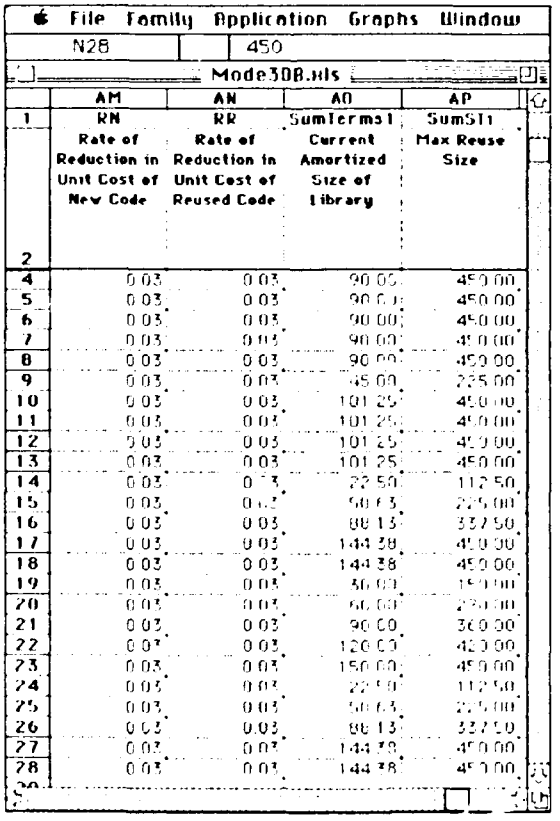
Mode30B.xls

	AF	AG	AH	AI	AJ	AK	AL
1	ROI	Ei	ISP	Ai	COM	BNi	JKi
2	Return on Investment	Library Efficiency	Incremental Spending Penalty	Ai	Cost of Money Per System	BNi	BRi
4	91 85	1 00	0 00	1 00	1216 65	1 00	1 00
5	91 85	1 00	0 00	0 00	973 32	1 00	1 00
6	91 85	1 00	0 00	0 00	729 99	1 00	1 00
7	91 85	1 00	0 00	0 00	486 66	1 00	1 00
8	91 85	1 00	0 00	0 00	243 33	1 00	1 00
9	70 87	1 00	0 50	0 50	608 33	1 00	1 00
10	70 87	1 00	0 50	0 50	1094 99	1 00	1 00
11	70 87	1 00	0 50	0 00	821 24	1 00	1 00
12	70 87	1 00	0 50	0 00	547 49	1 00	1 00
13	70 87	1 00	0 50	0 00	273 75	1 00	1 00
14	26 89	0	1 50	0 25	304 16	1 00	1 00
15	28 89	1 00	1 50	0 25	547 49	1 00	1 00
16	28 89	1 00	1 50	0 25	714 78	1 00	1 00
17	28 89	1 00	1 50	0 25	780 68	1 00	1 00
18	28 89	1 00	1 50	0 00	390 34	1 00	1 00
19	35 89	1 00	1 33	0 33	405 55	1 00	1 00
20	35 89	1 00	1 33	0 27	648 88	1 00	1 00
21	35 89	1 00	1 33	0 20	729 99	1 00	1 00
22	35 89	1 00	1 33	0 13	648 88	1 00	1 00
23	35 89	1 00	1 33	0 07	405 55	1 00	1 00
24	13 21	1 00	1 50	0 25	304 16	1 00	1 00
25	13 21	1 00	1 50	0 25	547 49	0 97	0 97
26	13 21	1 00	1 50	0 25	714 78	0 94	0 94
27	13 21	1 00	1 50	0 25	780 68	0 91	0 91
28	13 21	1 00	1 50	0 00	390 34	0 89	0 89

Figure 4-43. Mode 3 Window (part 5)



File Family Application Graphs Window

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Mode30B.xls

	AM	AN	AO	AP
1	RN	RR	Sumterms1	SumS11
2	Rate of Reduction in Unit Cost of New Code	Rate of Reduction in Unit Cost of Reused Code	Current Amortized Size of Library	Max Reuse Size
4	0 03	0 03	90 00	450 00
5	0 03	0 03	90 00	450 00
6	0 03	0 03	90 00	450 00
7	0 03	0 03	90 00	450 00
8	0 03	0 03	90 00	450 00
9	0 03	0 03	45 00	225 00
10	0 03	0 03	101 25	450 00
11	0 03	0 03	101 25	450 00
12	0 03	0 03	101 25	450 00
13	0 03	0 03	101 25	450 00
14	0 03	0 03	22 50	112 50
15	0 03	0 03	50 63	225 00
16	0 03	0 03	88 13	337 50
17	0 03	0 03	144 38	450 00
18	0 03	0 03	144 38	450 00
19	0 03	0 03	50 63	225 00
20	0 03	0 03	66 00	292 50
21	0 03	0 03	90 00	360 00
22	0 03	0 03	120 00	427 50
23	0 03	0 03	150 00	450 00
24	0 03	0 03	22 50	112 50
25	0 03	0 03	50 63	225 00
26	0 03	0 03	88 13	337 50
27	0 03	0 03	144 38	450 00
28	0 03	0 03	144 38	450 00

Figure 4-44. Mode 3 Window (part 6)

The worksheet contains the rows of data that either you entered or were computed from the values you entered. Each column of data corresponds to a variable described in the reuse economics model detailed in Cruickshank and Gaffney (1991) and summarized in Appendix A. Table 4-9 shows the mapping of column names to variable names.

NOTE: The sample data sets are for demonstration purposes only; you should build your own.

Table 4-9. Mapping of Worksheet Column Names to Reuse Economic Model Variable Names

Worksheet Column Label	Worksheet Column Name	Variable Name*	Constraints
A	Family Number	FamilyNo	$0 < \text{FamilyNo}$
B	Application Number	I	$0 < I$
C	Number of Application Systems	N	$0 < N$
D	Base Unit Cost of Reuse Program Investment	C_{DE}	$0 < C_{DE}$
E	Base Unit Cost of New Code	C_{VN}	$0 < C_{VN}$
F	Base Unit Cost of Reused Code	C_{VR}	$0 < C_{VR}$
G	Unit Cost of New Code for the i^{th} Application System	C_{VNi}	$0 < C_{VN_i}$
H	Unit Cost of Reused Code for the i^{th} Application System	C_{VRi}	$0 < C_{VR_i}$
I	Interest Rate	Rate	$0 \leq \text{Rate}$
J	Number of Years	Years	$0 \leq \text{Years}$
K	Amount of Reuse Library Associated With the i^{th} Application System	ST_i	$0 \leq ST_i$
L	Size of Reuse Library	ST	$ST = \sum_{i=1}^{N} ST_i$
M	Amount of New Code Developed for the i^{th} Application System	SN_i	$0 \leq SN_i$

Table 4-9, continued

Worksheet Column Label	Worksheet Column Name	Variable Name*	Constraints
N	Amount of Reused Code Incorporated in the i^{th} Application System	SR_i	$0 \leq SR_i \leq SumST_i$
O	Total Size of the i^{th} Application System	SS_i	$SS_i = SN_i + SR_i$
P	Proportion of Code Reuse for the i^{th} Application System	R_i	$R_i = SR_i/SS_i$
Q	Relative Library Capacity for the i^{th} Application System	K_i	$K_i = \sum_{m=1}^{i} ST_m/SS_i$
R	Unit Cost of i^{th} Application System	C_{USi}	$C_{US_i} = [(C_{DE}/SS_i)\cdot SumTerms1] + C_{VN_i} - [(C_{VN_i} - C_{VR_i})\cdot R_i]$
S	Cost of Product	C_S	$C_S = C_{US_i} \cdot SS_i$
T	Application Engineering Cost per System	C_{Ai}	$C_{A_i} = (C_{VN_i} \cdot SS_i) - [(C_{VN_i} - C_{VR_i})\cdot SR_i]$
U	Reuse Program Investment Cost per System	$C_{DE}SumTerms1$	$C_{DE}SumTerms1 = C_{DE} \cdot SumTerms1$
V	Reuse Program Investment	$C_{DE}ST_i$	$C_{DE}ST_i = C_{DE} \cdot ST_i$
W	Cost per System With All New Code	CT_i	$CT_i = C_{VN_i} \cdot SS_i$
X	Product Productivity	PU	$PU = 1,000/C_{US_i}$
Y	Relative Product Productivity	P	$P = C_{VN_i}/C_{US_i}$
Z	Relative Product Cost	C	$C = 1/P$
AA	Relative Reuse Cost	C_{VRR}	$C_{VRR} = C_{VR_i}/C_{VN_i}$
AB	Sum Cost of System With All New Code	$SumCT_i$	$SumCT_i = \sum_{i=1}^{N} CT_i$
AC	Sum Reuse Program Investment	$SumC_{DE}ST_i$	$SumC_{DE}ST_i = \sum_{i=1}^{N} C_{DE}ST_i$

Table 4-9, continued

Worksheet Column Label	Worksheet Column Name	Variable Name*	Constraints
AD	Sum Cost of Product	$SumCS_i$	$SumCS_i = \sum_{i=1}^{N} CS_i$
AE	Sum Cost of Money	$SumCOM_i$	$SumCOM_i = \sum_{i=1}^{N} COM_i$
AF	Return on Investment	ROI	$ROI = [(SumCT_i - SumC_{DE}ST_i - SumCOM_i)/SumC_{DE}ST_i] \cdot 100$
AG	Library Efficiency	E_i	$E_i = R_i/K_i$
AH	Incremental Spending Penalty	ISP	$ISP = \sum_{i=1}^{N}(i-1)\cdot a_i$
AI	Ai	a_i	$a_i = ST_i/ST$
AJ	Cost of Money	COM_j	$COM_j = \sum_{i=1}^{j} a_i \cdot CDE \cdot ST \cdot [1-(j-i)/(N-(i-1))] \cdot [(1+0.01\cdot Rate)^{Years}-1]$
AK	BNi	BN_i	$BN_i = (1-RN)^{(i-1)}$
AL	BRi	BR_i	$BR_i = (1-RR)^{(i-1)}$
AM	Rate of Reduction in Unit Cost of New Code	RN	$0 \le RN < 1$
AN	Rate of Reduction in Unit Cost of Reused Code	RR	$0 \le RR < 1$
AO	SumTerms1	SumTerms1	$SumTerms1 = \sum_{m=1}^{i}(ST_m/(N-(m-1)))$
AP	SumSTi	$SumST_i$	$SumST_i = \sum_{m=1}^{i} ST_m$

* Appendix A and Cruickshank and Gaffney (1991) use subscripts on some of these variables, such as C_{DE} instead of CDE and C_{US} instead of CUS.

4.6.1 The File Menu

The File menu provides the following options:

- Print Preview
  - To print the worksheet, select Print Preview from the File menu. The standard Microsoft Excel Print Preview window then appears.

  Note: Attempting to print when there is no printer connected may result in a macro error. Should this happen, click the [Halt] button to return to normal operation.

- Save
  - To save changes made to the worksheet, select Save from the File menu. The tool saves the data and returns you to the Mode 3 window. Saving a worksheet overwrites the previous data with the current data. The tool maintains only one version of the worksheet and makes it accessible through the application.
  - To retain old data indefinitely, make a copy of the file Mode3DB.xls under a new name. Do this outside of the Reuse Economics Spreadsheet Model tool.
  - To restore old data, rename a saved file to Mode3DB.xls. You should be able to print a saved worksheet from Microsoft Excel. Saving old data under different file names is a way to preserve historical data associated with a particular graph or set of graphs.

- Close
  - To exit the Mode 3 window:
    - Select Close from the File menu. A dialog box appears to warn you if you have any unsaved changes.
    - Click the [Yes] or [No] button, as appropriate, to continue the Close process. When the Close process completes, the Main window appears.

4.6.2 Dialog Box Description

The Family and Application menu operations use a common dialog box interface. The interface for Modify operations consists of a sequence of two dialog boxes. The interface for Add and Delete operations consists of a single dialog box that is identical to the second dialog box displayed for a Modify operation.

The first dialog box contains check boxes for each of the modifiable fields. It allows you to specify which fields you wish to modify, thus providing protection against inadvertent data modification. You must select the check boxes for those fields that you wish to modify. Clicking the [OK] button causes the next dialog box in the sequence to be displayed. Clicking the [Cancel] button terminates the current operation and returns control to the Mode 3 window.

The second dialog box contains list boxes, number edit boxes, and option buttons. It allows you to enter and display data corresponding to a selected family or application. The fields of the dialog box are enabled or disabled in accordance with the type of operation to be performed. For example, when

performing a family level operation, the Application Number list box is disabled. The list boxes are used for selecting family and application numbers. The enabled number edit boxes are used for entering data for the selected family or application. The disabled number edit boxes are used to display constraints or current data values for your convenience. The option buttons are used to select the desired form of unit cost scaling. For example, select Set Default on the CVN Scale Factors option button group to display or enter the RN value. Clicking the [Refresh] button updates the screen to display the dialog box with the current values for the selected family or application shown in the number edit boxes. Clicking the [Accept] button carries out the current operation and returns control to the dialog box. Clicking the [Cancel] button terminates the current operation and returns control to the Mode 3 window.

The fields that are modifiable at the family level include those that are modifiable at the application level in addition to:

- ***CDE.*** This field corresponds to the Base Unit Cost of Reuse Program Investment. All applications within a family have the same value for CDE. Due to an implementation constraint that requires a nonzero value for CDE, it is not possible to exactly model the situation where there is no Reuse Program Investment (i.e., you are reusing library components that have been supplied to you at no cost). However, you can approximately model that situation by supplying a small value (e.g., 0.001) for CDE. This may cause the Return on Investment field to display a value too large for the column width. Such a situation is indicated by the presence of ### instead of a numeric value in the worksheet cell.

- ***CVN.*** This field corresponds to the Base Unit Cost of New Code. All applications within a family have the same value for CVN. Each application may have a different CVN_i (Unit Cost of New Code for the i^{th} Application System), which is determined by adjusting the CVN Scale Factor (BN_i or RN) to obtain the desired CVN_i.

- ***CVR.*** This field corresponds to the Base Unit Cost of Reused Code. All applications within a family have the same value for CVR. Each application may have a different CVR_i (Unit Cost of Reused Code for the i^{th} Application System), which is determined by adjusting the CVR Scale Factor (BR_i or RR) to obtain the desired CVR_i.

The fields that are modifiable at the application level are:

- ***ST_i.*** This field corresponds to the Amount of Reuse Library Associated with the i^{th} Application System.

- ***SN_i.*** This field corresponds to the Amount of New Code Associated with the i^{th} Application System.

- ***SR_i.*** This field corresponds to the Amount of Reused Code Associated with the i^{th} Application System.

- ***CVN Scale Factor.*** This field corresponds to either BN_i or RN. When the RN option button is on, the Value number edit box corresponds to RN. Modification of RN is only applicable at the family level. When the BN_i option button is on, the Value number edit box corresponds to BN_i.

  NOTE: The CVN Scale Factor is used to compute CVN_i by the formula $CVN_i = BN_i \cdot CVN$. The default scaling formula used to compute BN_i is $BN_i = (1 - RN)^{(i-1)}$.

- ***CVR Scale Factor.*** This field corresponds to either BR_i or RR. When the RR option button is on, the Value number edit box corresponds to RR. Modification of RR is only applicable at the family level. When the BR_i option button is on, the Value number edit box corresponds to BR_i.

  NOTE: The CVR Scale Factor is used to compute CVR_i by the formula $CVR_i = BR_i \cdot CVR$. The default scaling formula used to compute BR_i is $BR_i = (1 - RR)^{(i-1)}$.

4.6.3 The Family Menu

The Family menu consists of those operations that can be performed at the family level. Any parameter values supplied to a family level operation are assigned to all application systems in the family. This allows you to perform gross editing functions, such as assignment of unit costs or allocation of reuse program investment, when such assignments are constant across the family. To perform detailed editing functions, you should use the operations available under the Application menu.

The Family menu provides the following options:

- Add Family
  - To add a family:
    - — Select Add Family from the Family menu. The Add Family Dialog Box then appears as shown in Figure 4-45.
    - — Enter values in the fields provided, and click the [Accept] button. The new rows will be added to the end of the existing worksheet data. All of the rows will be identified by the same Family Number, and each of the N rows in the family (where N is the Number of Application Systems) will have the values specified for the input fields.
  - To view an existing family, select the desired Family Number from the Family Number list box, and click the [Refresh] button. The data for the selected family will be shown in the corresponding dialog box fields.
  - Clicking the [Cancel] button will terminate the Add Family operation and return control to the Mode 3 window.

    NOTE: Pressing <RETURN> is the same as clicking the [Refresh] button.

EXAMPLE: To create a family with parameter values N = 5, CDE = 7.5, CVN = 5, CVR = 0.5, Interest Rate = 8, Years = 4, STi = 450, SNi = 50, SRi = 450, RN = 0.03, and RR = 0.03:

1. Select Add Family from the Family menu to display the Add Family Dialog Box (as shown in Figure 4-45).

2. If there is an existing family with similar parameter values, select the existing family number and click the [Refresh] button to display the parameter values for that family. Then modify the parameters to the appropriate values for the new family. If the dialog box contains the data as displayed in Figure 4-45, then no changes are necessary because all of the displayed values are correct.

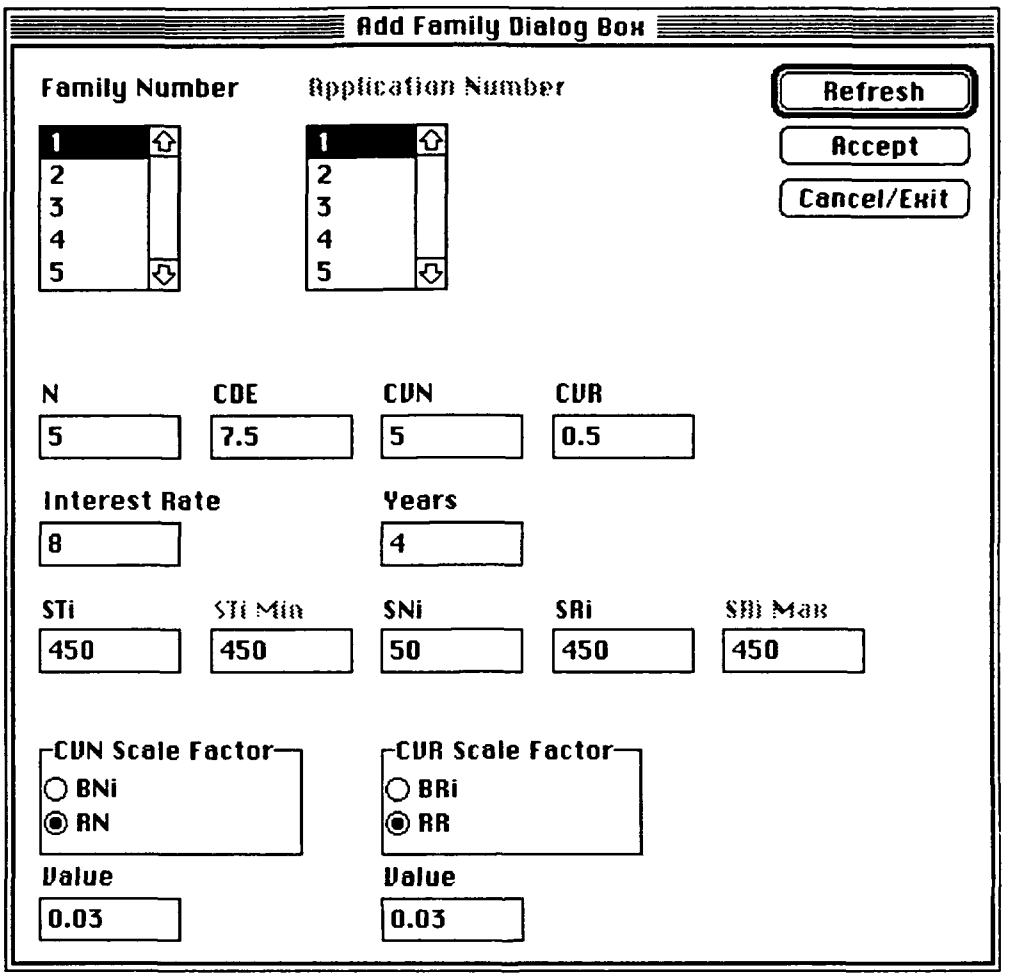

Figure 4-45. Mode 3—Add Family Dialog Box

3. If there is no existing family with similar parameter values, just modify the displayed parameter values that need to be changed for the new family.

4. Click the [Accept] button to create the new family.

5. Click the [Cancel] button to terminate the Add Family operation.

EXAMPLE: To create a family with parameter values N = 5, CDE = 7.5, CVN = 5, CVR = 0.5, Interest Rate = 8, Years = 4, ST1 = 225, ST2 = 225, ST3 = 0, ST4 = 0, ST5 = 0, SN1 = 275, SN2 = 50, SN3 = 50, SN4 = 50, SN5 = 50, SR1 = 225, SR2 = 450, SR3 = 450, SR4 = 450, SR5 = 450, RN = 0.03, and RR = 0.03:

1. Select Add Family from the Family menu to display the Add Family Dialog Box.

2. Modify the displayed parameter values to N = 5, CDE = 7.5, CVN = 5, CVR = 0.5, Interest Rate = 8, Years = 4, STi = 225, SNi = 50, SRi = 225, RN = 0.03, and RR = 0.03. There is a constraint that the value for SRi cannot be greater than the sum of the STi values up to and including the i^{th} application system. Therefore, SR1 must be less than or equal to ST1. Similarly, SR2 must be less than or equal to ST1 + ST2, etc.

3. Click the [Accept] button to create the new family.

4. Click the [Cancel] button to terminate the Add Family operation.

5. Perform the Modify Application System operation to adjust the values for STi, SNi, and SRi for each of the application systems in the newly created family.

- Modify Family
  - To modify a family:
    - Select Modify Family from the Family menu. The Modify Family Dialog Box1 then appears as shown in Figure 4-46.
    - Select the boxes corresponding to those values to be modified.
    - Click the [OK] button to proceed to Modify Family Dialog Box2 as shown in Figure 4-47.
    - Click the [Cancel] button to terminate the Modify Family operation.
    - To modify a group of rows representing a family, select the corresponding Family Number by clicking the mouse button to highlight the number in the Family Number list box of the Modify Family Dialog Box2. Enter those values that you wish to modify. Then click the [Accept] button. The rows of the selected family will be modified, and control will return to the Modify Family Dialog Box2.
  - Clicking the [Refresh] button will update the dialog box to display the current values for the selected family.
  - Clicking the [Cancel] button will terminate the Modify Family operation and return control to the Mode 3 window.

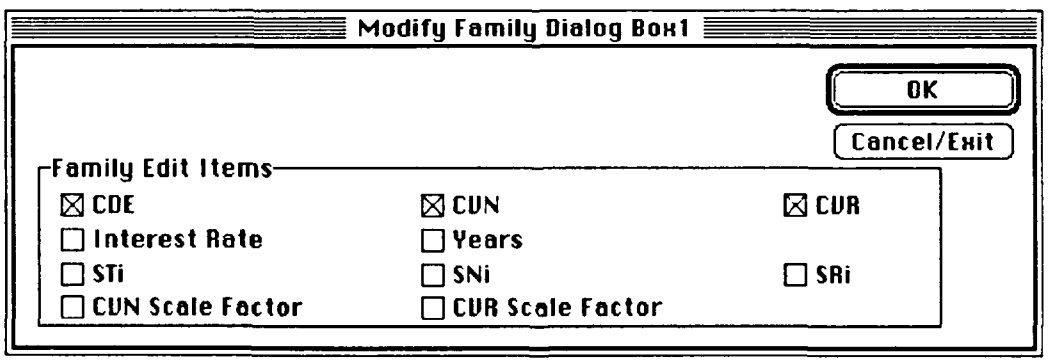

Figure 4-46. Mode 3—Modify Family Dialog Box1

EXAMPLE: To modify a family to set parameters CDE = 6, CVN = 8.5, and CVR = 1.5:

1. Select Modify Family from the Family menu to display the Modify Family Dialog Box1.
2. Select the check boxes for CDE, CVN, and CVR (as shown in Figure 4-46). Make sure the check boxes for nonmodifiable fields are deselected.

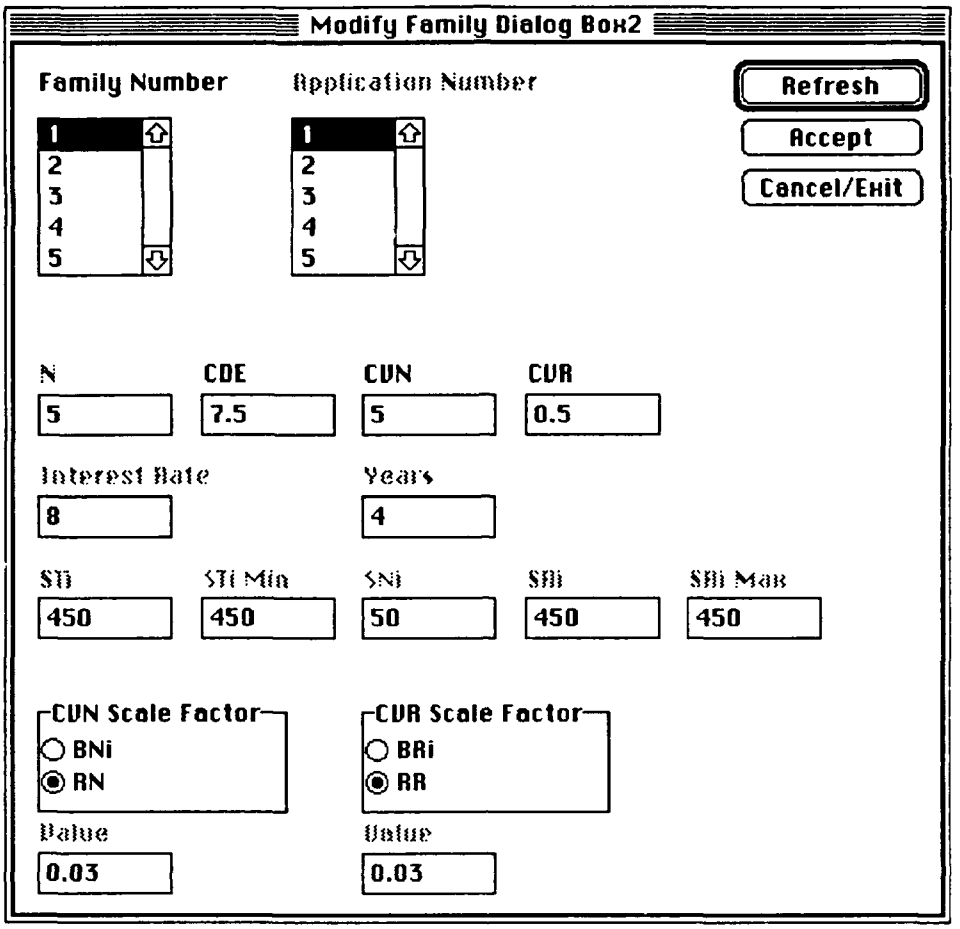

Figure 4-47. Mode 3—Modify Family Dialog Box2

3. Click the [OK] button to proceed to the Modify Family Dialog Box2 (as shown in Figure 4-47).
4. Select the Family Number for the family that you wish to modify.
5. Click the [Refresh] button to display the parameter values for the selected family.
6. Set the parameter values CDE = 6, CVN = 8.5, and CVR = 1.5 in the appropriate fields.
7. Click the [Accept] button to modify the selected family.
8. Click the [Cancel] button to terminate the Modify Family operation.

- Delete Family
  - To delete a family:
    -- Select Delete Family from the Family menu. The Delete Family Dialog Box then appears as shown in Figure 4-48.
    -- Select the corresponding Family Number by clicking the mouse button to highlight the number in the Family Number list box.
  - Clicking the [Accept] button will cause the Delete Confirmation Dialog Box to be displayed (see Figure 4-12).

— Click the [OK] button if you wish to proceed with the delete operation. The row of the selected family will be deleted and the remaining worksheet data will be renumbered to reflect the number of different families represented in the worksheet.

— Click the [Cancel] button if you wish to abort the delete operation.

- Clicking the [Refresh] button will update the dialog box with the current values for the selected family.

- Clicking the [Cancel] button will terminate the Delete Family operation and return control to the Mode 3 window.

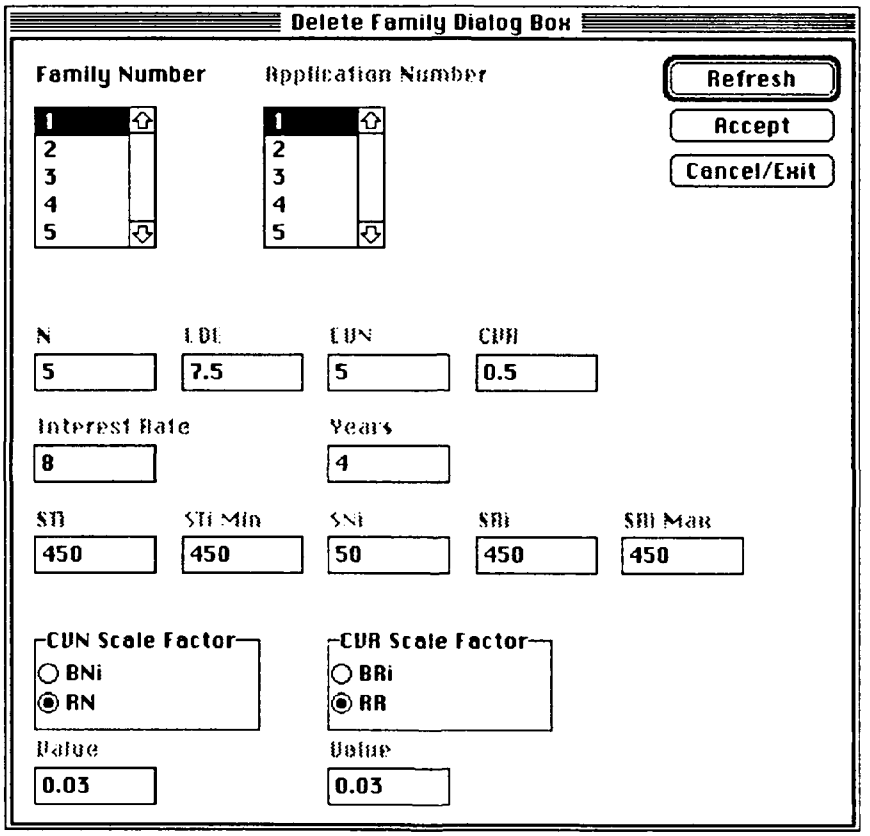

Figure 4-48. Mode 3—Delete Family Dialog Box

EXAMPLE: To delete Family Number = 1:

1. Select Delete Family from the Family menu to display the Delete Family Dialog Box (as shown in Figure 4-48).

2. Select Family Number = 1.

3. Click the [Refresh] button to display the parameter values for the selected family (just to make sure that you have selected the correct family).

4. Click the [Accept] button to proceed to the Delete Confirmation Dialog Box (as shown in Figure 4-12).

5. Click the [OK] button in the Delete Confirmation Dialog Box to delete the selected family and to display the Delete Family Dialog Box.

6. Click the [Cancel] button in the Delete Family Dialog Box to terminate the Delete Family operation.

4.6.4 The Application Menu

The Application menu provides the following options:

- Add Application System
  - To add N rows to a family:
    - Select Add Application System from the Application menu. The Add Application System Dialog Box then appears as shown in Figure 4-49.
    - Enter N in the Number of Application Systems field along with the desired values in the fields provided, and click the [Accept] button. The new rows will be added to the selected family after the selected application.
  - Clicking the [Refresh] button will update the screen to display the values for the selected application in the selected family.
  - Clicking the [Cancel] button will terminate the Add operation and return control to the Mode 3 window.

Example: To add three application system to a family:

1. Select Add Application System from the Application menu to display the Add Application System Dialog Box (as shown in Figure 4-49).
2. Select the Family Number of the family to be modified.
3. Select the Application Number of the application that you wish to use as a model for the new application systems.
4. Click the [Refresh] button to display the parameters for the selected application system.
5. Set the parameter value N = 3.
6. Click the [Accept] button to create three new application systems. If the selected application number = i, the added application systems will be duplicates of application system i and will be assigned application numbers i + 1, i + 2, and i + 3, respectively. The applications in the family will be renumbered to account for the added application systems.
7. Click the [Cancel] button to terminate the Add Application System operation.

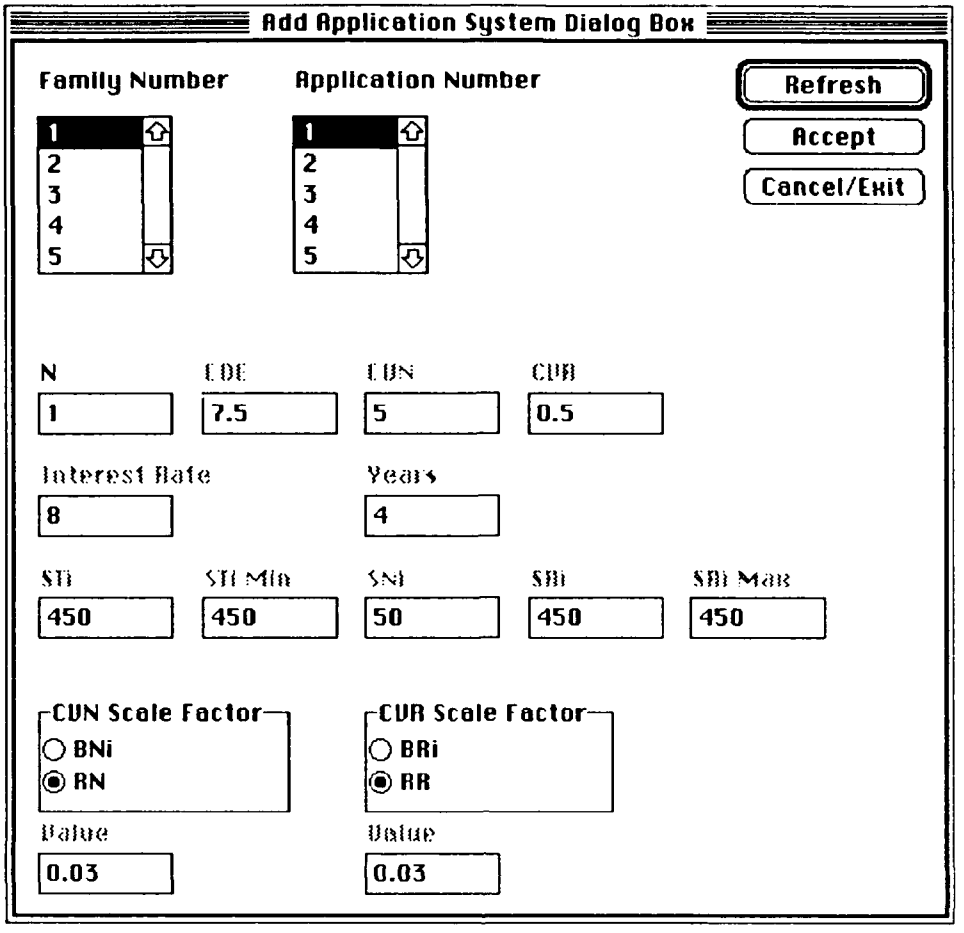

Figure 4-49. Mode 3—Add Application System Dialog Box

- Modify Application System
  - To modify an application within a family:
    - Select Modify Application System from the Application menu. The Modify Application System Dialog Box1 then appears as shown in Figure 4-50.
    - Select the boxes corresponding to those values that are to be modified.
    - Click the [OK] button to proceed to Modify Application System Dialog Box2 as shown in Figure 4-51.
    - Click the [Cancel] button to terminate the Modify Application System operation.
    - Select the corresponding family number and application number by clicking the mouse button to highlight the numbers in the Family Number and Application Number list boxes, respectively. Enter those values that you wish to modify. Then click the [Accept] button. The rows of the selected application will be modified, and control will return to the Modify Application System Dialog Box2.
  - Clicking the [Refresh] button will update the screen to display the current values for the selected application.

- Clicking the [Cancel] button will terminate the Modify Application System operation and return control to the Mode 3 window.

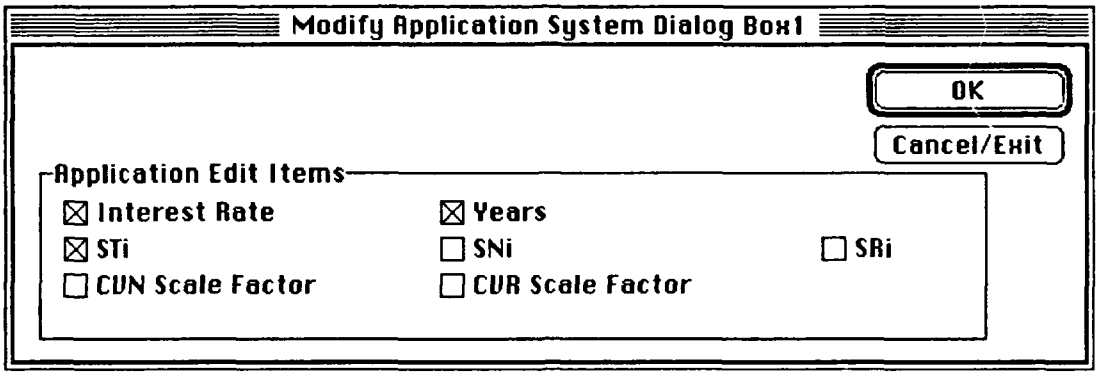

Figure 4-50. Mode 3—Modify Application System Dialog Box1

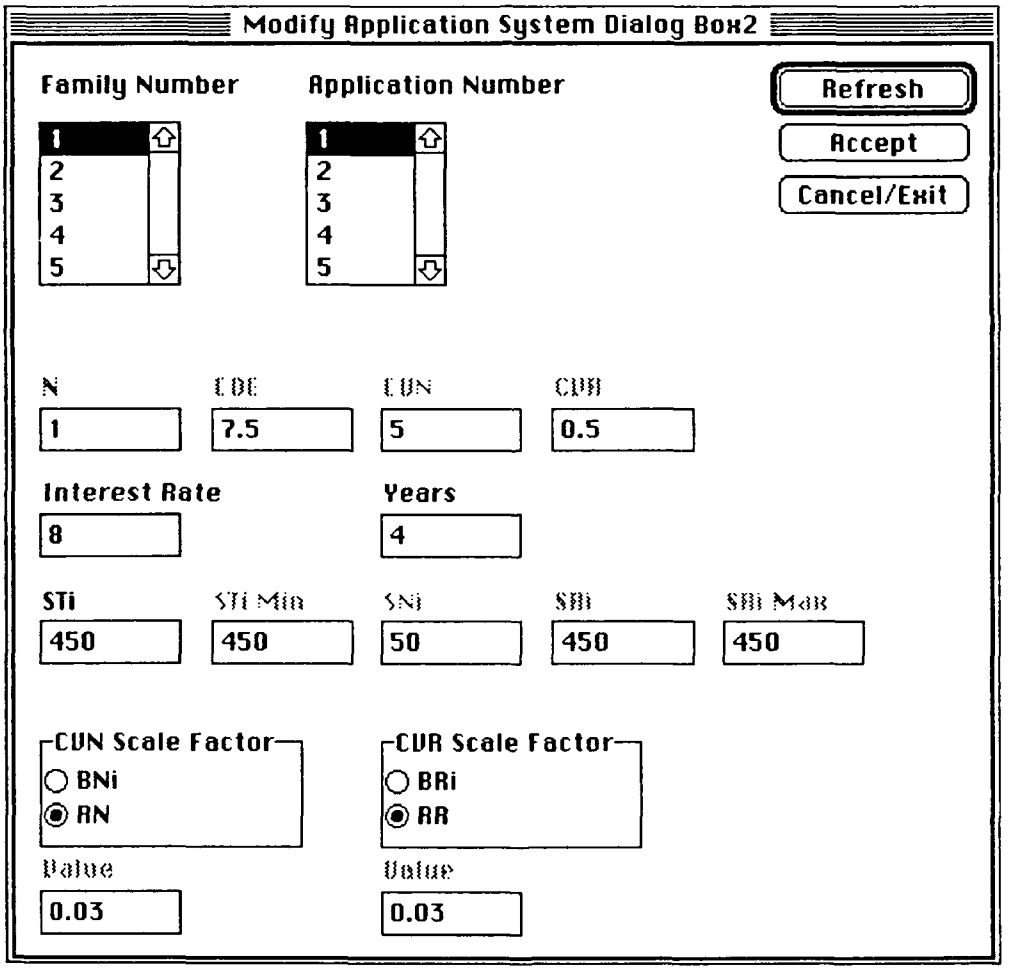

Figure 4-51. Mode 3—Modify Application System Dialog Box2

EXAMPLE: To modify the application systems in a family such that the parameter values are N = 5, CDE = 7.5, CVN = 5, CVR = 0.5, Interest Rate = 8, Years = 4, ST1 = 225, ST2 = 225, ST3 = 0, ST4 = 0, ST5 = 0, SN1 = 275, SN2 = 50, SN3 = 50, SN4 = 50, SN5 = 50, SR1 = 225, SR2 = 450, SR3 = 450, SR4 = 450, SR5 = 450, RN = 0.03, and RR = 0.03:

1. Select Modify Application System from the Application menu to display the Modify Application System Dialog Box1 (as shown in Figure 4-50).
2. Select the check boxes for STi, SNi, and SRi on the Modify Application System Dialog Box1.
3. Click the [OK] button to proceed to the Modify Application System Dialog Box2 (as shown in Figure 4-51).
4. Select the Family Number of the family to be modified.
5. Select Application Number = 1.
6. Click the [Refresh] button to display the parameters for the selected application system.
7. Set the parameter values STi = 225, SNi = 275, and SRi = 225.
8. Click the [Accept] button to modify the application system.
9. Select Application Number = 2.
10. Click the [Refresh] button to display the parameters for the selected application system.
11. Set the parameter values STi = 225, SNi = 50, and SRi = 450.
12. Click the [Accept] button to modify the application system.
13. Select Application Number = 3.
14. Click the [Refresh] button to display the parameters for the selected application system.
15. Set the parameter values STi = 0, SNi = 50, and SRi = 450.
16. Click the [Accept] button to modify the application system.
17. Select Application Number = 4.
18. Click the [Refresh] button to display the parameters for the selected application system.
19. Set the parameter values STi = 0, SNi = 50, and SRi = 450.
20. Click the [Accept] button to modify the application system.
21. Select Application Number = 5.
22. Click the [Refresh] button to display the parameters for the selected application system.
23. Set the parameter values STi = 0, SNi = 50, and SRi = 450.
24. Click the [Accept] button to modify the application system.
25. Click the [Cancel] button to terminate the Add Family operation.

- Delete Application System
  - To delete applications from a family:
    -- Select Delete from the Data menu. The Delete Dialog Box then appears as shown in Figure 4-52.

— Select the corresponding family number and application number from the Family Number and Application Number list boxes, respectively. Enter the number of applications to delete.

- Clicking the [Accept] button will cause the Delete Confirmation Dialog Box to be displayed (see Figure 4-12).

  — Click the [OK] button if you wish to proceed with the delete operation. The selected rows will be deleted from the selected family, and the remaining worksheet data will be renumbered to reflect the number of applications in the family.

  — Click the [Cancel] button if you wish to abort the delete operation.

- Clicking the [Refresh] button updates the screen to display the current values for the selected application.

- Clicking the [Cancel] button will terminate the Delete Application System operation and return control to the Mode 3 window.

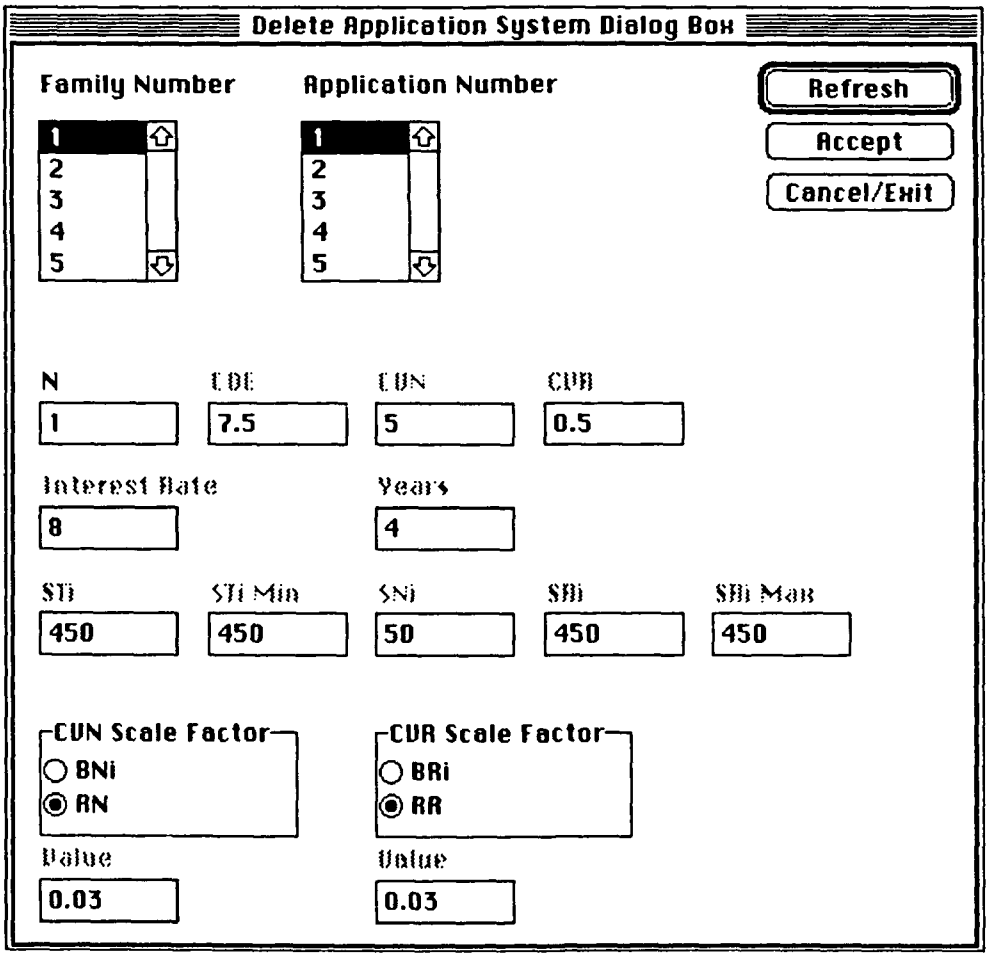

Figure 4-52. Mode 3—Delete Application System Dialog Box

EXAMPLE: To delete Application Number = 3 from Family Number = 2:

1. Select Delete Application System from the Application menu to display the Delete Application System Dialog Box (as shown in Figure 4-52).

2. Select Family Number = 2.

3. Select Application Number = 3.

4. Click the [Refresh] button to display the parameter values for the selected application system (just to make sure that you have selected the correct application).

5. Click the [Accept] button to proceed to the Delete Confirmation Dialog Box (as shown in Figure 4-12).

6. Click the [OK] button in the Delete Confirmation Dialog Box to delete the selected application and to display the Delete Application System Dialog Box.

7. Click the [Cancel] button in the Delete Application System Dialog Box to terminate the Delete Application System operation.

4.6.5 The Graphs Menu

The Graphs menu generates the built-in graph for Mode 3 calculations. A dialog box appears when you select a graph from the Graphs menu. The input dialog box allows you to specify the reuse scenario family number to be used in the graph. To produce a graph from the worksheet data, select the desired graph from the Graphs menu. There is one built-in graph that you can produce in Mode 3: Labor Months vs Number of Application Systems.

4.6.5.1 Labor Months vs Number of Application Systems Graph

The Labor Months vs Number of Application Systems graph provides a bar chart measuring Reuse Program Investment, Cost per System With All New Code, Application Engineering Cost per System, and Reuse Program Investment Cost per System for each of the N applications in the selected reuse scenario.

When entering your data, a dialog box appears (see Figure 4-53).

The Graph1 Inputs Dialog Box requests a value for the family number of the reuse scenario to plot.

- To specify a value for the family number:
  - Select a value from the corresponding list box.
  - Click the [OK] button to transmit the selected value to the application and continue building the graph.

    NOTE: Pressing <RETURN> in response to a dialog box is the same as clicking the [OK] button.

- Clicking the [Cancel] button will terminate the graph build operation and return control to the Mode 3 window.

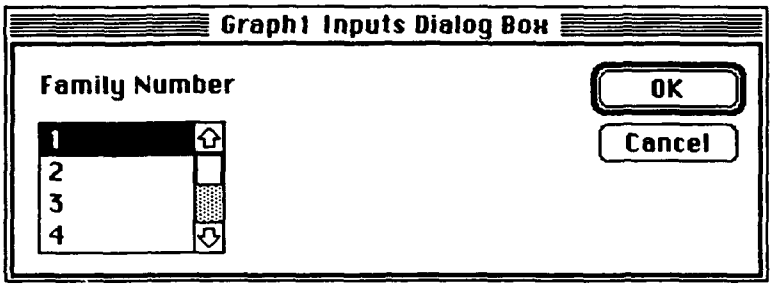

Figure 4-53. Mode 3—Graph1 Inputs Dialog Box

When you complete your entries, the graph window displays the resultant graph (see Figure 4-54).

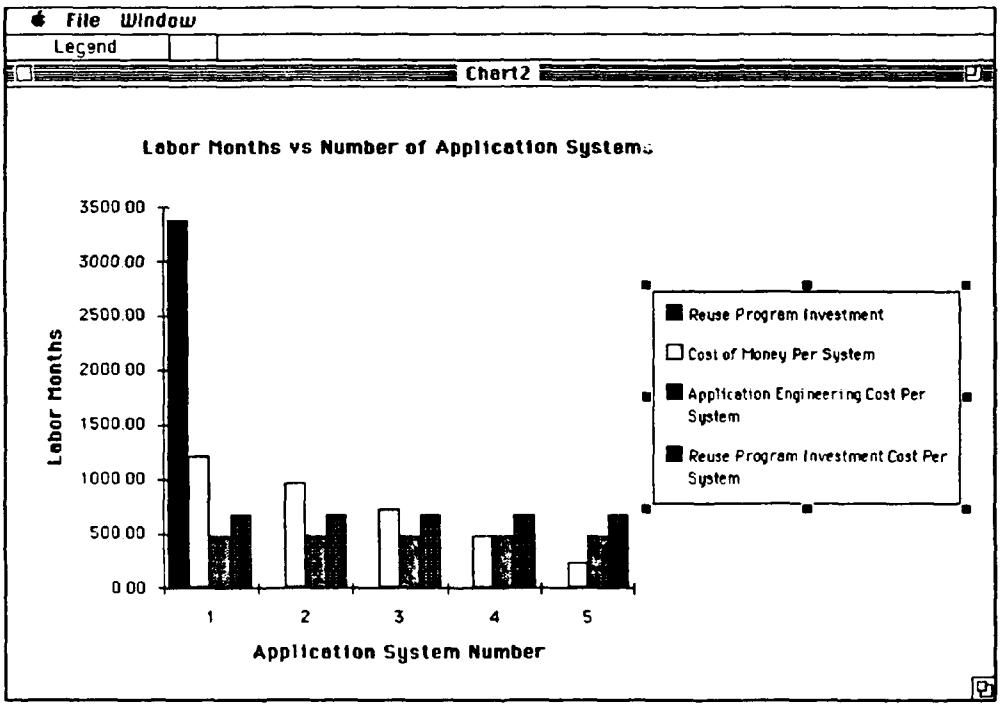

Figure 4-54. Mode 3—Graph1 Window

Table 4-10 shows the input data values that produced this graph.

EXAMPLE: The data for family 1 represents a case where there are five application systems in the family and all of the reuse program investment is done during development of the first application system in the family. All of the subsequent application systems reuse the library components that were developed for that first system. To generate the Labor Months vs Number of Application Systems Graph for Family Number = 1:

1. Select Labor Months vs Number of Application Systems from the Graphs menu to display the Graph1 Inputs Dialog Box (as shown in Figure 4-53).

Table 4-10. Input Data Values for Labor Months vs Number of Application Systems Graph Window

Application Number (i)	Number of Application Systems (N)	Base Unit Cost of Reuse Program Investment (C_{DE})	Base Unit Cost of New Code (C_{VN})	Base Unit Cost of Reused Code (C_{VR})	Amount of Reuse Library Associated With i^{th} Application System (ST_i)	Amount of New Code Developed for the i^{th} Application System (SN_i)	Amount of Reused Code Incorporated in the i^{th} Application System (SR_i)
1	5	7.5	5	0.5	450	50	450
2	5	7.5	5	0.5	0	50	450
3	5	7.5	5	0.5	0	50	450
4	5	7.5	5	0.5	0	50	450
5	5	7.5	5	0.5	0	50	450

2. Select Family Number = 1.

3. Click the [OK] button in the Graph1 Inputs Dialog Box to display the graph for the selected family (as shown in Figure 4-54).

4.6.6 The Window Menu

The Window menu provides the following options:

- ***Arrange All.*** To simultaneously display all open windows, select Arrange All from the Window menu. This is useful for viewing multiple graphs at the same time.

- ***Calculate Now.*** To update the values displayed on the worksheet, select Calculate Now from the Window menu. This is useful for deferring time consuming updates until they are requested by the user.

4.7 THE GRAPH WINDOW

The window for graphs appears when you select a graph from the Graphs menu. It provides access to all other system functions allowed for graphs.

The Graph window consists of a custom Microsoft Excel menu and a Microsoft Excel chart containing the specified graph (see Figure 4-54). The menu bar contains the File and Window menus. The File menu allows you to print the chart, save the chart, and return to the window from which you invoked the Graph menu option. The Window menu allows you to arrange multiple windows so that all are displayed simultaneously. The chart plots the selected worksheet data in accordance with the parameters you specify in the graph input dialog boxes.

The default naming convention followed for graphs is Chart?, where the question mark is replaced by a digit (starting at 1) that is incremented for each graph created during a single session. Selecting the Save option from the File menu causes the Graph Save Dialog Box to appear (see Figure 4-55). You may save graphs to the default file name or to a user specified name.

NOTE: Saving a graph in a directory other than the current working directory will result in a macro error.

You may also print a saved graph using the Print or Print Preview options of the standard Microsoft Excel File menu. When opening a saved graph under standard Excel, you will be presented with a dialog box requesting you to "update references to unopened documents." You must click the [No] button to display the graph as it was saved. Clicking the [Yes] button results in the graph being recomputed using default data that does not correspond to the saved graph. You should rename saved graphs to avoid naming conflicts that can occur when saving subsequent graphs. Should you encounter a naming conflict, a dialog box appears requesting confirmation to overwrite the existing graph. Click the [OK] button to overwrite the existing graph.

NOTE: Clicking the [Cancel] button causes a macro error dialog box to appear. To recover from this error, click the [Halt] button to restore normal operation.

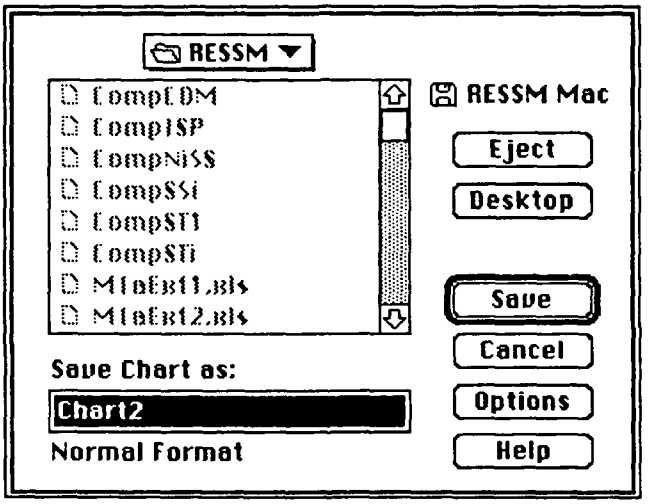

Figure 4-55. Graph Save Dialog Box

APPENDIX A. REUSE ECONOMICS MATHEMATICAL MODELS

A.1 OVERVIEW

This appendix provides a detailed description of the models implemented in the Reuse Economics Spreadsheet Model tool.

A.2 MODE 1a—REUSE WITH UP-FRONT REUSE PROGRAM INVESTMENT (DOMAIN ENGINEERING)

A.2.1 Mode 1a Overview

Mode 1a implements the basic reuse economics model that represents the cost of developing one of a family of application systems. The cost of domain engineering is assumed to be incurred all at once, up front, with respect to the development of a family of N systems and is spread uniformly (prorated) over them.

A.2.2 Basic Unit Cost Equation

An application system consists of two categories of code: **new** and **reused**. Development labor costs are assignable to these two categories of code (Gaffney and Cruickshank 1992; IEEE 1993). Symbolically, an application system of S_S KSLOC is composed of S_N KSLOC of new code and S_R KSLOC of reused code. Thus:

$$S_S = S_N + S_R$$

where:

- S_N = Amount of new code in KSLOC developed for this application system
- S_R = Amount of reused code (from the reuse library), in KSLOC, incorporated into this application system
- S_S = Total size of the application system in KSLOC

The proportion of code reuse, R, is given by the relationship:

$$R = S_R/S_S \text{ thus } (1-R) = S_N/S_S$$

The reuse economics model reflects the total cost of developing an application system in which there is investment in the creation of RSOs that are incorporated into a family of application systems. The

model implemented in Mode 1a treats the cost of an application system as the sum of the cost of the capital investment in domain engineering apportioned over expected N application systems plus the cost of application engineering (the cost of creating that particular system).

The cost of an application system, C_S, is equal to the sum of the prorated cost of domain engineering plus the cost of developing the new code for this system, C_N, plus the cost of reusing code from the repository or other source, C_R. The expression for C_S is:

$$C_S = C_D/N + C_N + C_R$$

Now, consider each of the costs, C_S, C_D, C_N, and C_R, to be the product of a unit cost (e.g., in LM/KSLOC) and code size (in KSLOC). Therefore, each of these costs can be expressed as follows:

C_S = The total cost of an application system, $C_{US} \cdot S_S$

C_D = The total cost of domain engineering investment, $C_{DE} \cdot S_T$

C_N = The cost of the new code in the application system, $C_{VN} \cdot S_N$

C_R = The cost of reusing code in the application system, $C_{VR} \cdot S_R$

S_T is the expected value of the unduplicated size of the reuse library, i.e., the available, reusable functionality (software code objects measured in KSLOC) in the library, and C_{US}, C_{DE}, C_{VN}, and C_{VR} are unit costs:

C_{US} = Unit cost of the application system.

C_{DE} = Unit cost of domain engineering.

C_{VN} = Unit cost of new code developed for this application system.

C_{VR} = Unit cost of reusing code from the reuse library in this application system. It represents the unit cost of reused code in the case where the library components can be instantiated directly into the application system with no modification.

Thus, the expression for C_S can be written as:

$$C_S = C_{US} \cdot S_S = (C_{DE} \cdot S_T)/N + (C_{VN} \cdot S_N) + (C_{VR} \cdot S_R)$$

Now, divide this equation by S_T, recall that $R = (S_R/S_S)$, and define K as follows:

K = The library relative capacity $(= S_T/S_S)$

This is the average proportion of the function of each of the N applications that the library covers. Note that R is upper-bounded by K, or:

$$0 \leq R \leq K$$

Then, you obtain the following expression for the basic unit cost equation with up front domain engineering investment, which is:

$$C_{US} = \frac{C_{DE}}{N} \cdot K + C_{VN} - (C_{VN} - C_{VR}) \cdot R$$

This expression and the one for C_{US}, from which it was derived, assume that each application system in the family of N such systems is of the same size, has the same amount of reused code, and has the same unit costs for developing new code and reusing code. Alternatively, this expression can be considered to represent the average application system in the family of N systems. Modes 2 and 3, in addition to representing the more general case of incremental domain engineering, permit the selection of values for C_{VN}, C_{VR}, S_S, S_N, and S_R for each application system in the family of systems.

You should note that the up-front domain engineering effort can be performed before the first N application systems in the family are created. Alternatively, it might be performed simultaneously with the creation of that system.

You should further note that the model without the domain engineering term

$$C_{US} = C_{VN} - (C_{VN} - C_{VR}) \cdot R$$

can be used to represent the case in which the cost of developing software components that are to be reused in a number of systems is borne by the development effort that creates them. In this case, the cost of making such software components may be said to be "expensed." This is the mode of reuse that has probably been most widely employed to date.

All of the equations used in Mode 1a are shown in Section 4.4.

A.2.3 Efficiency of Use of the Library Infrastructure

The efficiency of use of the library infrastructure, E, is a metric that captures the degree to which the system has incorporated RSOs from the library of reusable components. If the system used 50% of the reusable components from the library, then E would be equal to 0.5. E is the ratio of the amount of reused function in an application system to the reusable function available from the library. This metric is stated in terms of S_R, the amount of reused code in the application system, S_T, the unduplicated code size of the reuse library or its capacity, and S_S, the size of the application system. The relationship among the parameters involved in the calculation of E are:

$$E = \frac{R}{K} = \frac{S_R/S_S}{S_T/S_S} = \frac{S_R}{S_T}$$

where $0 \leq E \leq 1$.

It is important to note that there may well be alternate or duplicate implementation functionality in the reuse library source code but that alternate or duplicate functionality does **not** add to the size of S_T. The case in which there are alternative implementations of some of the functionality is covered by an appropriate selection of the cost parameter C_{DE}, the unit cost of domain engineering (Gaffney and Cruickshank 1992). When there is more than one alternative of some functionality, the unduplicated code size, S_T, is the same as in the case of one alternative, but the unit cost of domain engineering, C_{DE}, will be larger to cover the cost of multiple alternatives.

The factor E indicates the extent to which the developer of a new application system has been able to make use of the library of reusable components in creating the new application system. E is a measure of the reuse application process efficiency. It is desirable that E be equal to or slightly less than

1.0 because a development organization would be expected, on average, to reuse as much code as possible when composing an application system.

Assuming that $S_R = S_T$ (which means K = R and E = 1), you can rewrite the basic reuse unit cost equation as:

$$C_{US} = \frac{C_{DE}}{N} \cdot R + C_{VN} - (C_{VN} - C_{VR}) \cdot R$$

Consolidating terms gives you:

$$C_{US} = C_{VN} - \left(C_{VN} - C_{VR} - \frac{C_{DE}}{N} \right) R$$

This equation is a form of the basic reuse unit cost equation with K = R. The (average) cost of an application in the family, C_S, is obtained by multiplying C_{US} by S_S, the total size of the application system, or:

$$C_S = C_{US} \cdot S_S$$

Therefore:

$$C_S = C_{VN} \cdot S_S - \left(C_{VN} - C_{VR} - \frac{C_{DE}}{N} \right) \cdot S_R$$

A.2.4 Return and Return on Investment

The **ROI** for reuse program investment is equal to the difference (in LM) between developing N application systems composed of all new code and developing N application systems composed, in part, with reused code. It takes into account the cost of reuse program investment. The **percent** ROI is equal to the return divided by the cost of reuse program investment times 100. It can be shown by the expression:

$$ROI = \left[\frac{N \cdot E \cdot (C_{VN} - C_{VR})}{C_{DE}} - 1 \right] \cdot 100$$

A.2.5 Break-Even Number of Systems

The break-even number of systems, N_0, is the number of systems required for the ROI to be equal to zero. If N is greater than N_0, reuse pays off. If N is less than N_0, reuse does not pay off. The expression for N_0 is:

$$N_0 = \frac{C_{DE}}{(C_{VN} - C_{VR})E}$$

The expression for ROI can be written more simply than in the expression above in terms of N and N_0:

$$ROI = \left[\frac{N}{N_0} - 1\right] \cdot 100$$

A.3 REUSE WITH INCREMENTAL DOMAIN ENGINEERING (REUSE PROGRAM INVESTMENT)

This section presents the cost model implemented in Modes 2 and 3. Mode 2 does not consider the cost of money; Mode 3 does. These modes use a generalization of the basic reuse economics model presented earlier to cover the case in which the reuse program investment is done incrementally, i.e., not done entirely at once, up front. It also allows any particular application system, say the i^{th}, to have a unique size (S_{Si}), a unique amount of reused code (S_{Ri}) and proportion of reuse (R_i), and unique unit costs for developing new code (C_{VNi}) and for reusing code (C_{VRi}).

A.3.1 Cost Models for Incremental Reuse Program Investment

Recall that the basic reuse economics model represents the case in which all of the reuse program investment is completed either before the first application system is produced or coincidental with its development. For certain domains and environments, this may be the case, but reuse program investment does not necessarily have to be done in this fashion. Reuse program investment may be done incrementally (i.e., piecewise), with some reuse program investment being done in conjunction with more than one of the N application systems produced from the domain (Cruickshank and Gaffney 1991 and 1993; Gaffney and Cruickshank 1992).

Consider the S_T KSLOC of unduplicated code in the reuse library that is to be used in one or more of the N application systems to be produced from the domain. Suppose that S_{T1} KSLOC is developed in association with system number 1, S_{T2} KSLOC is developed in association with system number 2, and so on. In general, S_{Ti} will be developed in association with system number i. Thus, $0 \le S_{Ti} \le S_T$ and $S_T = \Sigma S_{Ti}$ for $i = 1,...,N$. Also, S_T can be given by the expression:

$$S_T = \Sigma\,(S_{Ti} = a_i \cdot S_T)$$

where the a_i vary between 0 and 1. S_{T1} is amortized over N application systems, S_{T2} is amortized over N–1 systems, and, in general, S_{Ti} is amortized over N–(i–1) systems. Let S_{Ri} be the size (in KSLOC) of the reused portion of application system i. Then, for the i^{th} system of the N application systems, the unit cost can be shown to be:

$$C_{USi} = \left(\frac{C_{DE}}{S_{Si}}\right) \sum_{m=1}^{i} \left(\frac{S_{Tm}}{N-(m-1)}\right) + C_{VNi} - (C_{VNi} - C_{VRi}) \cdot R_i$$

where C_{VNi} is the unit cost of developing new code for system i, C_{VRi} is the cost of reusing code in system i, and R_i is the proportion of reuse in the i^{th} system. This is the basic reuse unit cost equation for incremental reuse program investment (covering more than one increment or period of time) and is the generalized version of the basic unit cost equation for up-front reuse program investment that

was discussed previously. The cost, i.e., the effort in LM or LH, required to produce application system i is obtained by multiplying through by S_{Si}. It is:

$$C_{Si} = C_{USi} \cdot S_{Si}$$

An alternative expression for the unit cost of application system i is now shown. It is developed from the one shown above by substituting for R_i an expression in E_i, the library use efficiency for system i. The library efficiency of application system i, E_i, is given by the expression:

$$E_i = S_{Ri}/\Sigma S_{Tm} \text{ for } m = 1,..,i$$

Then, the general unit cost equation for incremental (including up-front) reuse program investment can be shown to be:

$$C_{USi} = \left(\frac{C_{DE}}{S_{Si}}\right) \sum_{m=1}^{i} \left(\frac{S_{Tm}}{N-(m-1)}\right) + C_{VNi} - (C_{VNi} - C_{VRi}) \cdot \left(E_i \cdot \sum_{m=1}^{i} S_{Tm}\right) \cdot \left(\frac{1}{S_{Si}}\right)$$

A.3.2 Selecting Values of C_{VN} and C_{VR} for a Specific System (Modes 2 and 3)

When operating the Reuse Economics Spreadsheet Model tool in Modes 2 or 3, you can select the values of C_{VN} and C_{VR} for a specific system, e.g., the i^{th}. This is not permitted for Mode 1a operation. Call these parameters C_{VNi} and C_{VRi} for the i^{th} system. They are the unit costs of developing new code for system i and reusing code in system i, respectively. You can select them in one of two ways. You can select each of them in terms of a base value for C_{VN} or C_{VR} times a variation factor, b_{Ni} or b_{Ri}, respectively, which is a function of the application number, i, or you can select them directly.

The forms used are:

$$C_{VNi} = b_{Ni} \cdot C_{VN} \quad \text{and} \quad C_{VRi} = b_{Ri} \cdot C_{VR}$$

Thus, you enter the two baseline values C_{VN} and C_{VR}, the N b_{Ni} values, and the N b_{Ri} values.

Second, the tool allows you to enter the two baseline values C_{VN} and C_{VR} and the two values r_N and r_R, where:

$$b_{Ni} = (1 - r_N)^{i-1} \quad \text{and} \quad b_{Ri} = (1 - r_R)^{i-1}$$

where r_N and r_R, $0 < r_N$, or $r_R < 1$ are the rates of reduction in developing new code and reusing code, respectively, per application system.

The tool provides preset baseline values of $C_{VN} = 5.0$ LM/KSLOC, $C_{VR} = 0.5$ LM/KSLOC, and $r_N = r_R = 0.03$. You may select other values for these parameters depending on the type of software that you are developing or the improvements in reuse technology and software development that you anticipate during the period of development of the members of the family of application systems that you are considering.

Substituting $C_{VN} \cdot b_{Ni}$ for C_{VNi} and $C_{VR} \cdot b_{Ri}$ for C_{VRi} in the equation given earlier for the unit cost of the i^{th} application system for the case of incremental reuse program investment, we obtain the unit cost of the i^{th} application system as:

$$C_{USi} = \left(\frac{C_{DE}}{S_{Si}}\right) \sum_{m=1}^{i} \left(\frac{S_{Tm}}{N-(m-1)}\right) + C_{VN} \cdot b_{Ni} - (C_{VN} \cdot b_{Ni} - C_{VR} \cdot b_{Ri}) \cdot R_i$$

A.3.3 Break-Even Number of Systems

For reuse to pay off, the cost of developing a family of N systems in which there is reuse must be less than the cost of developing each of them from entirely new code as described in Section A.2.5. The break-even number of systems, N_0, is defined as the number of systems (the size of the family) at which these two costs would be equal. For reuse to pay off, N must be greater than N_0. The break-even number of systems, N_0, is the value of N when the two costs are equal or when:

$$\sum_{i=1}^{N_0} C_{VNi} \cdot S_{Si} = \sum_{i=1}^{N_0} C_{USi} \cdot S_{Si}$$

Under the conditions $C_{VNi} = C_{VN}$, $C_{VRi} = C_{VR}$, and $E_i = E$ for all i, it can be shown that:

$$N_0 = \frac{C_{DE}}{(C_{VN} - C_{VR}) \cdot E} + P$$

where:

$$P = \sum_{i=1}^{N} (i-1) \cdot a_i = \sum_{i=1}^{N} i \cdot a_i - 1$$

P is the **incremental spending penalty**. This is the additional number of application systems beyond those required for break-even if up-front reuse program investment is used. Funding reuse program investment incrementally has the penalizing effect of increasing the number of systems required to break even compared with doing reuse program investment all at once. However, incremental funding has the advantages of flexibility and capital preservation. Also, by delaying some of your investment, you may be able to have better information on which to base decisions concerning the development of RSOs. Therefore, delaying some of the investment may be cost effective. The Reuse Economic Model Spreadsheet tool does not compute N_0 for Modes 2 and 3; it does for Mode 1a.

A.3.4 Selection of Some Parameter Values for Modes 2 and 3

It is important to note that when operating the Reuse Economics Spreadsheet Model tool in either Mode 2 or 3, you may select different values for the parameters C_{VN} and C_{VR} for each application system in the family whose development cost structure you are investigating. You can then use the model and the tool to represent the situation in which the costs of developing new code or reusing code can change during the period of development of the application systems of the family of interest. These unit costs would be expected to decrease over this period corresponding to improvements in software process and the technology or tools that support it.

The model and the tool allow you to select one value of C_{DE}, the unit cost of reuse program investment. C_{DE} is applied in the computation of the costs of developing the increment of the reusable code of total size S_T to be developed during the period of creation of the N application systems in a family. You can choose the value of C_{DE} to cover the variation expected in the unit cost of reuse program investment over the period of development of the family. One approach would be to select the average value of C_{DE} expected for that period.

It is recognized that, in some instances, the RSOs in the library will "age" during the period of development of the application systems in a family. This would be a secondary effect in many situations. You may wish to select the value of C_{DE} or S_T that you employ in your cost modeling effort to reflect this aging effect. For example, if you believe that, over the period of interest, some of the software will become of no value (will age), you could either raise the value of C_{DE} or S_T beyond that value you selected based on other considerations.

A.4 MODE 2—REUSE WITH INCREMENTAL REUSE PROGRAM INVESTMENT WITHOUT COST OF MONEY

This section applies the incremental domain engineering or program investment model to Mode 2 operations. Mode 2 does not include considerations of the cost of money; Mode 3, covered in Section A.5, does.

A.4.1 Incremental Reuse Program Investment Example

This section illustrates the application of the model of reuse with incremental domain engineering but without cost of money, summarized in Section A.3, to four examples of cases of five application systems in a family. Each case presents a different strategy of incremental reuse program investment funding. The ROI is calculated for each case and is shown in the bottom of Table A-1 for each of the four cases. The amount of the total library code, S_T, developed in connection with application system i, is symbolized by S_{Ti}. The S_{Ti} values for each of the four cases presented here are shown in Table A-2.

Table A-1. Costs for Four Alternative Reuse Program Investment Strategies (Without Cost of Money)

System	Cost per System Without Reuse & Domain Engineering	Case 1		Case 2		Case 3		Case 4	
		Domain Engineering Investment Increment (LM)	Cost per System (LM)	Domain Engineering Investment Increment (LM)	Cost per System (LM)	Domain Engineering Investment Increment (LM)	Cost per System (LM)	Domain Engineering Investment Increment (LM)	Cost per System (LM)
1	2.500	3.375	1.150	1.687.5	1.825.0	843.75	2.162.5	1.125	2.050
2	2.500	—	1.150	1.687.5	1.234.4	843.75	1.867.2	900	1.735
3	2.500	—	1.150	—	1.234.4	843.75	1.642.2	675	1.555
4	2.500	—	1.150	—	1.234.4	843.75	1.557.8	450	1.510
5	2.500	—	1.150	—	1.234.4	—	1.557.8	225	1.600
Totals (1)	12.500	3.375	5.750	3.375.0	6.762.6	3.375.00	8.787.5	3.375	8.450
Savings (2)		6.750 (= 12.500 - 5.750)		5.737.4 (= 12.500.0 - 6.762.6)		3.712.5 (= 12.500.0 - 8.787.5)		4.050 (= 12.500 - 8.450)	
% ROI = Savings/3.375		200		170		110		120	

Table A-2. Library Code Development Allocations

Case Number	Library Code Allocation
1	$S_{T1} = S_T$
2	$S_{T1} = S_{T2} = S_T/2$
3	$S_{T1} = S_{T2} = S_{T3} = S_{T4} = S_T/4$
4	$S_{T1} = (5/15)S_T$; $S_{T2} = (4/15)S_T$; $S_{T3} = (3/15)S_T$; $S_{T4} = (2/15)S_T$; $S_{T5} = (1/15)S_T$

Each of the examples of application systems has the same values of: C_{VN} (=5 LM/KSLOC), C_{VR} (=0.5 LM/KSLOC), C_{DE} (=7.5 LM/KSLOC), S_S (=500 KSLOC), S_T (=450 KSLOC), and E (=1.0). Thus, in each of these examples, $C_{VNi} = C_{VN}$ (a fixed value) and $C_{VRi} = C_{VR}$ (a fixed value) for all i (all five family members for each case). The fact that E=1 for each application system means that it reuses all of the unique code in the library that exists at the time it is constructed. All investment and cost figures are in LM. In Table A-1, 12,500 LM is the total cost of developing five application systems using all new code (without reuse). Further, in Table A-1, $C_{VN} \cdot S_S = 5.000 \cdot 500 = 12{,}500$ LM is the total cost of developing five new application systems (without reuse), and $C_{DE} \cdot S_T = 7.500 \cdot 450 = 3{,}375$ LM is the total investment in a reuse program spread over N=5 application systems.

The cost of application system i, C_{Si}, for each application system in a family is given in the column labeled "Cost per System" for each case shown in Table A-1. The formula used to compute those values, under the conditions that each system is of the same size (S_S) and has the same unit costs of new code development and of code reuse (C_{VN} and C_{VR}, respectively), is:

$$C_{Si} = C_{DE} \sum_{m=1}^{i} \left(\frac{S_{Tm}}{(N-(m-1))} \right) + C_{VN}S_S - (C_{VN} - C_{VR}) \cdot E_i \cdot \sum_{m=1}^{i} S_{Tm}$$

Further, given that $E_i = 1.0$ for each application system, the following formula is used:

$$C_{Si} = C_{DE} \sum_{m=1}^{i} \left(\frac{S_{Tm}}{(N-(m-1))} \right) + C_{VN}S_S - (C_{VN} - C_{VR}) \sum_{m=1}^{i} S_{Tm}$$

Here, the symbols C_{VN} and C_{VR} rather than C_{VNi} and C_{VRi}, respectively, are used because these unit costs are the same for each of the five family members.

To illustrate the calculation for allocating the incremental reuse program investment to each application system in a family, consider the Case 4 investment strategy. Table A-3 shows the apportionment. Recall from Table A-2 that the initial amount of usable code developed, S_{T1}, was spread over all five systems; its cost, as shown in Table A-3, is (7.5)(450/15)(5) = 1,125 LM. The second amount of reusable code developed, S_{T2}, was spread over the last four systems; its cost, as shown in Table A-3, is (7.5)(450/15)(4) = 900 LM. You sum across the rows in Table A-3 to determine if the amount of reuse program investment is pro rata assumed by the application system in the family corresponding to that

row. That number is equal to the value of the reuse program investment term in the equation for C_{Si} above. That term is:

$$C_{DE} \sum_{m=1}^{i} \left(\frac{S_{Tm}}{(N-(m-1))} \right)$$

Table A-3. Reuse Program Investment Apportionment per System for Case 4

System	Reuse Program Investment Increment (LM)					Reuse Program Investment per System (LM)
	Of S_{T1}	Of S_{T2}	Of S_{T3}	Of S_{T4}	Of S_{T5}	
1	7.5(450/15)	—	—	—	—	225
2	7.5(450/15)	7.5(450/15)	—	—	—	450
3	7.5(450/15)	7.5(450/15)	7.5(450/15)	—	—	675
4	7.5(450/15)	7.5(450/15)	7.5(450/15)	7.5(450/15)	—	900
5	7.5(450/15)	7.5(450/15)	7.5(450/15)	7.5(450/15)	7.5(450/15)	1,125
Total LM	1,125	900	675	450	225	3,375

Now, we consider several examples of calculating the entries in Table A-1, labeled "Cost per System."

The first example is for Case 1. Here, $S_{T1} = S_T$. This is the case in which all of the reuse program investment is done up front (the situation represented by the model employed in Mode 1a). In this case, the cost of reuse program investment is apportioned equally to each of the five application systems:

$$C_{S1} = 7.5\left(\frac{450}{5}\right) + 5.000(500) - 4.5(450) = 675 + 2,500 - 2,025 = 1,150 \text{ LM}$$

In this case, the investment in a reuse program is apportioned uniformly over the five application systems; therefore, each of the five systems costs 1,150 LM.

The next example is for Case 2, in which $S_{Ti} = S_T/2$ for $i = 1$ and $i = 2$. The first system will cost:

$$C_{S1} = 7.5\left(\frac{450/2}{5}\right) + 5.000(500) - 4.5\left(\frac{450}{2}\right) = 337.5 + 2,500.0 - 1,012.5 = 1,825.0 \text{ LM}$$

The second through the fifth systems will each cost:

$$C_{S2} = 7.5\left(\frac{450/2}{5} + \frac{450/2}{4}\right) + 5.000(500) - 4.5\left(\frac{450}{2} + \frac{450}{2}\right)$$

$$C_{S2} = 337.5 + 421.875 + 2,500 - 2,025 = 1,234.4 \text{ LM}$$

A.4.2 Savings and Return on Investment

In each of the four cases considered, the savings resulting from developing systems in part from reused code instead of entirely new code are equal to the difference between the costs of developing the systems using all new code and developing them with some reused code. The savings are given by:

$$\text{Savings} = C_{VN} \cdot S_S \cdot N - \sum_{i=1}^{N} C_{Si}$$

Table A-1 illustrates the method for calculating the savings and the ROI. The percent ROI is:

$$\text{ROI} = \left(\frac{\text{Savings}}{C_{DE} \cdot S_T} \right) \cdot 100$$

Generally, for the situation of different values of unit cost of developing new code and of application system size, the formula for savings for the family of N application systems is:

$$\text{Savings} = \sum_{i=1}^{N} C_{VNi} \cdot S_{Si} - \sum_{i=1}^{N} C_{Si}$$

All of the equations used in Mode 2 are shown in Section 4.5.

A.5 MODE 3—REUSE WITH INCREMENTAL REUSE PROGRAM INVESTMENT WITH COST OF MONEY

This section describes the model underlying Mode 3 operations. Mode 3 application system costs include a term for cost of money. This term is an addition to terms in the Mode 2 expression for the cost of an application system for the prorated reuse program investment cost, the cost of developing new code (for this particular application system), and the cost of reusing code in this application system. This section applies the incremental reuse program investment model to Mode 3 operations. The Section A.3 presentation on incremental reuse program investment and the Section A.4 presentation on Mode 2 operations do not consider the cost of money. This section shows two cases of five application systems in which the cost of money is calculated and included in the costs of each of the application systems. The two cases used are Cases 1 and 4 from Section A.4 in which they were considered without the cost of money. They are reconsidered here with the cost of money terms added.

The treatment of reuse with incremental reuse program investment **and** cost of money is similar to that in Section A.4 for the situation in which the cost of money is not considered. Note that Tables A-4 and A-5 in this section, which relate to reuse program investment apportionment, are analogous to Table A-3 in Section A.4. They differ only with respect to the inclusion of cost of money values in the two tables in this section but not in Table A-3 in Section A.4. Further, you will note that Table A-6 in this section differs from Table A-1 in Section A.4 only in that it includes values for cost of money.

A.5.1 Cost of Money

The cost of money is an element of cost that many business organizations should consider when making decisions about investing in reuse program investment. The cost of money models presented here are discussed in detail in Cruickshank and Gaffney (1991).

Table A-4. Reuse Program Investment Apportionment per System With Cost of Money for Case 1

Reuse Program Investment Stream											
	Stream 1		Stream 2		Stream 3		Stream 4		Stream 5		
Appl. Sys.	Cost of Money	Principal	Cost of Money	Principal	Cost of Money	Principal	Cost of Money	Principal	Cost of Money	Principal	Total Cost of Money
1	1216.65	675	—	—	—	—	—	—	—	—	1,216.65
2	973.32	675	—	—	—	—	—	—	—	—	973.32
3	729.99	675	—	—	—	—	—	—	—	—	729.99
4	486.66	675	—	—	—	—	—	—	—	—	486.66
5	243.33	675	—	—	—	—	—	—	—	—	243.33
Total	—	3,375	—	—	—	—	—	—	—	—	3,649.95

Table A-5. Reuse Program Investment Apportionment per System With Cost of Money for Case 4

Reuse Program Investment Stream											
	Stream 1		Stream 2		Stream 3		Stream 4		Stream 5		
Appl. Sys.	Cost of Money	Principal	Cost of Money	Principal	Cost of Money	Principal	Cost of Money	Principal	Cost of Money	Principal	Total Cost of Money
1	405.55	225	—	—	—	—	—	—	—	—	405.55
2	324.44	225	324.44	225	—	—	—	—	—	—	648.88
3	243.33	225	243.33	225	243.33	225	—	—	—	—	729.99
4	162.22	225	162.22	225	162.22	225	162.22	225	—	—	648.88
5	81.11	225	81.11	225	81.11	225	81.11	225	81.11	225	405.55
Total	—	1,125	—	900	—	675	—	450	—	225	2,828.85

Table A-6. Costs for Two Alternative Reuse Program Investment Strategies With Cost of Money

		Case 1				Case 4			
System No.	Cost per System Without Reuse and Domain Engineering	Reuse Program Investment (LM)	Domain Engineering and Application Engineering Cost per System (LM)	Cost of Money (Interest) (LM)	Cost per System (LM)	Reuse Program Investment (LM)	Domain Engineering and Application Engineering Cost per System (LM)	Cost of Money (Interest) (LM)	Cost per System (LM)
1	2,500	3,375	1,150	1,217	2,367	1,125	2,050	406	2,456
2	2,500	–	1,150	973	2,123	900	1,735	649	2,384
3	2,500	–	1,150	730	1,880	675	1,555	730	2,285
4	2,500	–	1,150	487	1,637	450	1,510	649	2,159
5	2,500	–	1,150	243	1,393	225	1,600	406	2,006
Totals	12,500	3,375	5,750	3,650	9,400	3,375	8,450	2,480	11,290
Savings		3,100 (= 12,500 - 9,400)				1,210 (= 12,500 - 11,290)			
% ROI = Savings/3,375		92				36			

The calculation of the cost of money can be organized as an N-by-N array (as shown in Tables A-4 and A-5), in which the columns correspond to reuse program investment "streams" and the rows correspond to the costs for each of these streams for each of the N application systems. A stream is an allocated flow of money, cost of money plus principal, to finance an increment of reuse program investment. For example, Stream 1 begins at application system 1 and corresponds to the reuse program investment increment made at system 1 and is amortized over all N systems. Stream 2 corresponds to the reuse program investment increment made at system 2 and is amortized over N–1 systems, etc. In any cell of the N-by-N computational array, the cost of money is the product of the portion of investment borrowed for system j under investment stream i and the cost of borrowing for y years at p percent annually.

The formula for the cost of money in any cell in the N-by-N array (only the lower triangular form is used) is:

$$I_{i,j} = \left[a_i \cdot C_T - (j-i) \cdot \left(\frac{a_i \cdot C_T}{N-(i-1)} \right) \right] \cdot [(1 + 0.01p)^y - 1] = F_1 \cdot F_2$$

where:

F_1 = Amount of reuse program investment borrowed for a system in investment stream i.

F_2 = Proportion, cost of money. For example, 0.36 means that 36 percent of F_1 can comprise cost of money (i_j), or I_{ij}.

This formula simplifies to:

$$I_{i,j} = a_i \cdot C_T \cdot \left[1 - \frac{j-i}{N-(i-1)} \right] \cdot [(1 + 0.01p)^y - 1]$$

where:

p = Annual percent interest rate

y = Number of years to which each investment increment is applicable

C_T = Total reuse program investment

a_i = Proportion of total reuse program investment ($C_T = C_{DE} \cdot S_T$) applied in stream i (a_i is defined in Section A.4)

T_j = Total cost of money for application system j, where:

$$T_j = \sum_{i=1}^{j} I_{i,j}$$

Two of the four cases, Cases 1 and 4, discussed in Section A.4 are now used as examples of the calculation of the cost of money.

Assume that there is a family of five application systems from the domain in question and that a system can be produced from a domain in 4 years. Also, assume that the current interest rate is 8% per annum.

All calculations are in LM, and the same parametric values as in Section A.4 are used: S_S = 500 KSLOC, S_T = 450 KSLOC, C_{DE} = 7.5 LM/KSLOC, C_{VN} = 5.0 LM/KSLOC, and C_{VR} = 0.5 LM/KSLOC.

The data in Table A-1 for Case 1 indicates that 3,375 LM are borrowed for 4 years at 8% to finance the up-front reuse program investment effort as applied to application system 1. Because 675 LM (= 1/5 x 3,375) are amortized by application system 1, then 2,700 LM (= 3,375 - 675) are amortized by system 2 and are borrowed for 4 years (the period of time between the start of development of successive systems). Similarly, 2,025 LM are borrowed for the next 4 years and so on. Note that these are the entries in Table A-4, which applies to Case 1 for Stream 1 only. This is because there is only one increment of reuse program investment in this case, all up front. Thus, in this case, $S_{T1} = S_T$ and $a_1 = 1$; $a_i = 0$ and $i = 2, 3, 4, 5$.

In Case 4, there are five increments of reuse program investment streams as shown in Table A-5:

$S_{T1} = 1{,}125 = 0.333 \times 3{,}375;\quad a_1 = 0.333$
$S_{T2} = 900 = 0.267 \times 3{,}375;\quad a_2 = 0.267$
$S_{T3} = 675 = 0.200 \times 3{,}375;\quad a_3 = 0.200$
$S_{T4} = 450 = 0.133 \times 3{,}375;\quad a_4 = 0.133$
$S_{T5} = 225 = 0.067 \times 3{,}375;\quad a_5 = 0.067$

Table A-6 summarizes the calculations for the cost of developing the application systems for Cases 1 and 4. The costs have been rounded to the nearest LM.

A.5.2 Comments on Cost of Money

The least costly course of action is to borrow the entire cost of reuse program investment at the beginning of the domain building effort (Case 1), just as with the previous analysis of incremental reuse program investment.

A.5.3 Savings and Return on Investment

In each of the two examples of cases considered for Mode 3, the savings that result from including reused code in the application systems instead of composing them from all new code are equal to the difference between the costs of developing the systems using all new code and developing them with some reused code. The savings are given by:

$$\text{Savings} = C_{VN} \cdot S_S \cdot N - \sum_{i=1}^{N} C_{Si} - \sum_{i=1}^{N} T_i$$

Table A-6 illustrates the method for calculating the savings and the ROI. The % ROI is:

$$\text{ROI} = \left(\frac{\text{Savings}}{C_{DE} \cdot S_T} \right) \cdot 100$$

Generally, for the situation of different values of unit cost of developing new code and of application system size, the formula for savings for the family of N application systems is:

$$\text{Savings} = \sum_{i=1}^{N} C_{VNi} \cdot S_{Si} - \sum_{i=1}^{N} C_{Si} - \sum_{i=1}^{N} T_i$$

All of the equations used in Mode 3 are shown in Section 4.5.

GLOSSARY

Application Engineering Cost per System	The unit cost of building the i^{th} application system in a family of application systems that make up a reuse scenario. This figure excludes the cost of reuse program investment.
Average Size of Application System	The size of the average application system in total lines of code.
Base Unit Cost of New Code	The baseline value to be used in computing unit cost of new code. The unit cost for each application system may vary from this baseline value by specifying an appropriate value for the Rate of Reduction in Unit Cost of New Code.
Base Unit Cost of Reuse Program Investment	The baseline value to be used in computing unit cost of the capital investment to create reusable software objects. The unit cost for each application system may vary from this baseline value by specifying an appropriate value for the Rate of Reduction in Unit Cost of Reuse Program Investment.
Base Unit Cost of Reused Code	The baseline value to be used in computing unit cost of reused code. The unit cost for each application system may vary from this baseline value by specifying an appropriate value for the Rate of Reduction in Unit Cost of Reused Code.
Break-even Number of Systems	The minimum number of application systems in a family of systems required for the return on reuse program investment to be positive.
Cost of Money per System	The interest paid on borrowed funds to develop each application system in a family.
Cost of Product	The cost of building an application system in which there is reuse.
Cost per System With All New Code	The unit cost of building an application system in which there is no reuse.

Current Amortized Size of Library	The size of the reuse library available to the i^{th} application system amortized over the number of applications systems developed since the library component was created.
Incremental Spending Penalty	The extra number of application systems required to break even because of incremental reuse program investment.
Interest Rate	The annual interest rate for borrowing funds over a specified period of years.
Library Efficiency	The ratio of the average amount of functionality reused in each application system of a family to the reusable functionality available in the library.
Max Reuse Size	The size of the reuse library available to be reused by the i^{th} application system.
Number of Years	The time during which interest is paid on borrowed funds.
Percent Return on Investment	The return divided by the cost of reuse program investment times 100.
Product Productivity	The ratio of 1,000 to the unit cost of a product.
Proportion of Code Reuse	The ratio of the amount of reused code to the total amount of code in an application system.
Rate of Reduction in Unit Cost of New Code	The parameter used to vary the unit cost of new code when that variance is assumed to take the form of compound interest.
Rate of Reduction in Unit Cost of Reuse Program Investment	The parameter used to vary the unit cost of reuse program investment when that variance is assumed to take the form of compound interest.
Rate of Reduction in Unit Cost of Reused Code	The parameter used to vary the unit cost of reused code when that variance is assumed to take the form of compound interest.
Relative Library Capacity	The ratio of the size of the reuse library to the average size of an application system.
Relative Product Cost	The ratio of the unit cost of a product to the unit cost of its new code component.
Relative Product Productivity	The ratio of the unit cost of the new code component of a product to its overall unit cost. This is the inverse of Relative Product Cost.

Relative Reuse Cost	The ratio of the unit cost of reused code to the unit cost of new code.
Reuse Program Investment	The amount of capital investment in the reusable software associated with building a family of application software systems.
Reuse Program Investment Cost per System	The pro rata portion of reuse program investment cost borne by a given application system.
Return	The difference in cost between producing N application systems with no reuse and producing N application systems with reuse, including the cost of reuse program investment.
Size of Reuse Library	The unduplicated code size of the library in total lines of code.
Unit Cost of i^{th} Application System	The unit cost of building the i^{th} application system of a family of application systems, taking into account the costs of new code and reusing code, and the pro rata cost of reuse program investment for the set of application systems in the family.
Unit Cost of New Code	The unit cost of new code developed for this application system.
Unit Cost of New Code for the i^{th} Application System	The unit cost of new code for the i^{th} application system is computed from the Base Unit Cost of New Code and the Rate of Reduction in Unit Cost of New Code.
Unit Cost of Product	The unit cost of building an application system, taking into account the costs of reuse program investment and code reuse.
Unit Cost of Reuse Program Investment	The unit cost of the capital investment to create reusable software objects.
Unit Cost of Reuse Program Investment for the i^{th} Application System	The unit cost of the capital investment to create reusable software objects for the i^{th} application system. The unit cost is computed from the Base Unit Cost of Reuse Program Investment and the Rate of Reduction in Unit Cost of Reuse Program Investment.
Unit Cost of Reused Code	The unit cost of reusing code from the reuse library in this application system.
Unit Cost of Reused Code for the i^{th} Application System	The unit cost of reused code for the i^{th} application system is computed from the Base Unit Cost of Reused Code and the Rate of Reduction in Unit Cost of Reused Code.

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